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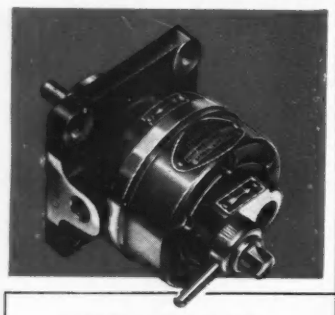

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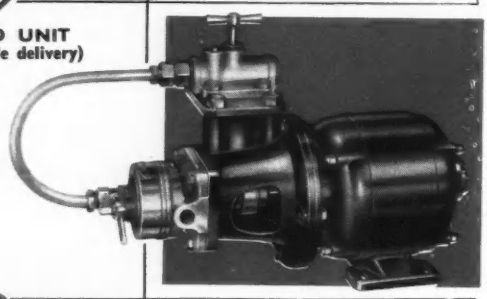

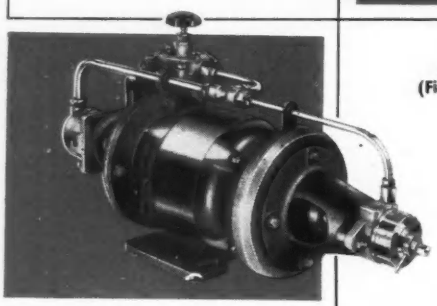

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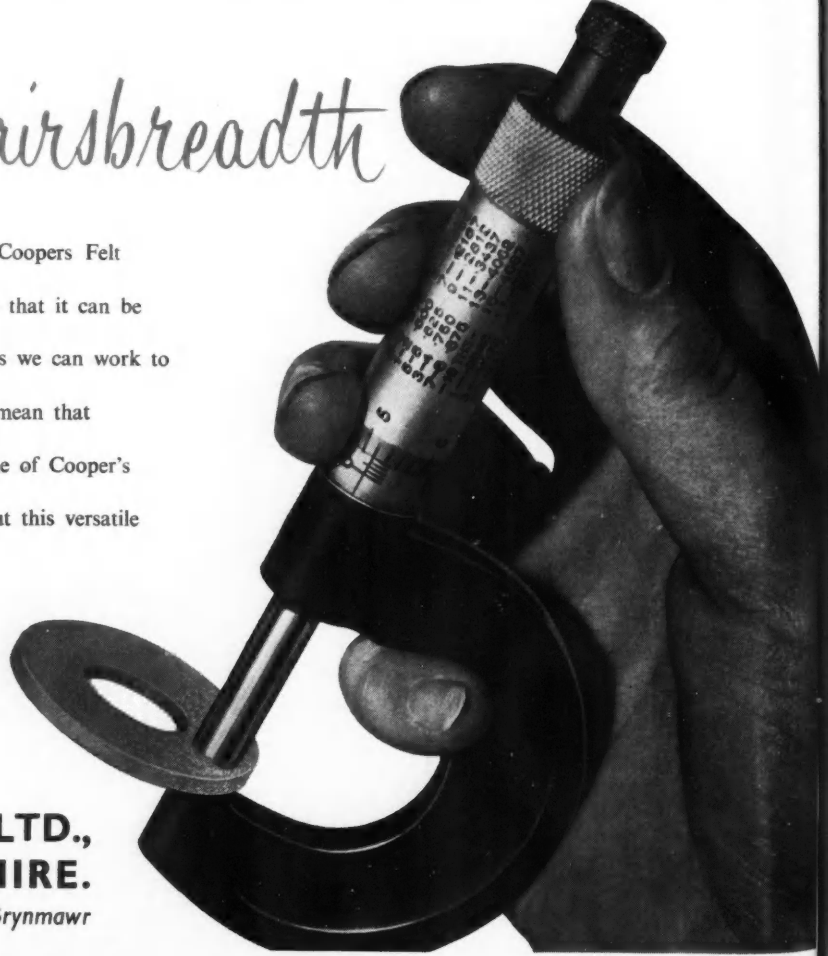

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THE ENGINEER

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MACMILLAN'S CABINET

It is not often that we comment in an editorial upon a Prime Minister's work in building up a Government. But Mr. Macmillan's Cabinet making is notable on two grounds. First of all he has gone outside the ranks of politicians to find a Minister of Power; and he has placed within that Ministry responsibility not only for the functions of the previously existing Ministry of Fuel and Power relating to coal, gas, electricity and oil, but also for the development of nuclear energy and for the iron and steel industry. A large fraction of those affairs of Government which affect the technology of industry will thus be in the hands of Sir Percy Mills, who, not being a member of the Commons, is to become a baron and a member of the House of Lords. This fraction of the affairs of Government will now be under the administration of an industrialist, not a politician, a man of proved ability and a man whose experience fits him to appreciate and act upon the advice of technologists. To us this seems important. For within the fields covered by the new Minister's activities, the majority of the decisions need to be taken not upon political grounds, with all the overtones of emotion which the use of that adjective implies, but upon their technological merits. Moreover, no Minister unable properly to comprehend those technological factors can be expected adequately to support the interests of the industries he serves in Cabinet discussions.

The other change which is particularly to be welcomed is that of the elevation of the Minister of Transport and Civil Aviation to Cabinet rank. Considering how important to the wellbeing of a country its systems of transport are, it is astonishing to us that for so long the Ministry of Transport has been regarded as a junior one, one that Ministers have regarded as a stepping-stone to higher posts. The Minister of Transport, we think, ought permanently, whoever is the holder of the office, to be within the Cabinet. We dare to hope that this elevation of a hitherto undervalued ministry may foreshadow a change in the policy of the Government. At long last the modernisation of the railways of this country has been well begun. Within a few years, everyone hopes, there will be much to show for it. But the roads are in as much need—indeed, of much greater need—of modernisation; and present plans fall very far short of meeting what becomes with every year that passes a more urgent necessity. Road engineers know that if they were allowed really to get ahead with reconstruction and new building they could save hundreds and possibly thousands of lives each year; and the more the monetary figures are examined, the clearer it becomes that an investment in improved roads would bring big financial returns even where, as in driving new roads through congested cities, the initial outlay would be very large. Only Government reluctance to make the finance available holds back the work. But now that the Minister of Transport is himself a member of the Cabinet he will, we hope, represent at that, the highest possible level, what all concerned with roads are thinking. Instead of having to accept a brief that he has had little hand in composing and endeavouring to make the best of it, he will now play a large part in the making of the brief itself. We hope Mr. Watkinson will make his presence felt in the Cabinet!

"NOTHING RECEDES LIKE SUCCESS"

"Nothing recedes like success." Those were the words of Mr. D. L. Wiggins at the luncheon preceding this year's conference, at Southampton University, on "Problems of Aircraft Production," and few of his hearers can have appreciated his meaning more fully than Mr. R. Maudling, then Minister of Supply. When he, in his turn, spoke, he bore out this text when he recalled the history of flight at supersonic speeds. The early failure of this country to build manned supersonic aircraft resulted in a substantial and enduring lead being achieved by the U.S.A. Success, as engineers are well aware, comes to an intricate and advanced project as a result of able development work. The magnitude of the development engineer's task was made clear by Mr. Maudling when he pointed out that as much might be spent on the development as on the production of an aircraft. This somewhat startling statement is, however, borne out by observation; for instance, such a powerful purchaser as the United States Air Force has adopted a bomber of English Electric origin, and in Canada a variant of the machine we regard as the vindication of turbo-prop plant is being built with Turbo-Compound engines for maritime reconnaissance. That much the same relation held good during the last war was the theme of the Lord Sempill paper: Herr K. Frydag believed that the increase

—over 100 per cent—in German fighter production during 1944, when Allied bombing was aimed at destroying the industry concerned, was due to a changed policy concentrating on the very minimum of different aircraft. Thus, since the short-term policy of the Ministry of Supply may well be more aircraft for less money, it is to be expected that the number of projects in hand will be reduced.

There are, of course, obvious objections in the way of implementing this administratively attractive proposition. Perhaps the greatest is that it involves a considerable risk. If any one project proves to be beyond the abilities of the development staff there is no other design for that requirement proceeding. However, the fact that all our three V-bombers, advanced as they were at the time of their inception, have matured so successfully as to justify their use by the squadrons shows that this risk is not too large to be acceptable, at least by a nation that does not stand, like the U.S.S.R., without allies. In the U.S.A., it is to be noted, only Boeing have designed strategic bombers since the last war. A further justification for taking this risk is that, when once an aircraft has achieved a highly developed state, it will be, in war, a better proposition for a task other than its own than a machine designed specifically for that task but less well developed. An example easily recalled is the "Beaufighter," which exploited its excellence as an aiming platform not only as a destroyer, but also offensively in the torpedo strike, attack bombing, and close support roles. That a weapon which has overtaken the swiftly receding state of being abreast of the art is worth a heavy burden of logistic and training difficulty is accepted by the fighting services: the Royal Navy uses American airborne early warning equipment, the Royal Artillery the "Corporal" missile, and Bomber Command the B-29 "Superfortress."

But to introduce this policy presents a contentious problem in deciding upon what to concentrate. The dictum of Herr Frydag—"Projects which cannot be expected to yield practical success for any reason should be stopped forthwith"—will not, we earnestly hope, exclude any of our current undertakings. A criterion was indicated, however, by the Minister in his address, namely, comparison with the achievements of the only other major aircraft industry in the capitalist countries, that of the U.S.A.; for we cannot afford to pursue a costly development programme if it will not furnish a more effective weapon than any already to hand in the Western world. The advantage of this criterion is that it can hardly fail to result in major curtailments of our commitments, since in some directions we have persisted with efforts too weak to catch up with success. An example that cannot escape attention is the carrier-borne all-weather aircraft: the Royal Navy expects to wait "some years" to be equipped with the D.H. 110, which, like the "Javelin," first flew late in 1951 and was conceived at a time when all-weather operation was expected to need a crew of two. This origin is reflected in a subsonic performance and great size: the weight is undoubtedly over 15 tons and the span is 51ft. But the U.S. Navy has recently decided that it will not adopt the "Skylancer," apparently purely for fiscal reasons, for, as we remarked in these columns last week, offensive action is the first concern of the Bureau of Aeronautics. The "Skylancer" is also an all-weather fighter and its predecessor (the "Skyray") first flew in 1951, but having been originally a day fighter, in which form it held a world speed record, it is a single-seater. In its present form it can carry missiles, rockets or bombs, does Mach 1·5, weighs perhaps 12 tons (and even the steam catapult has its limits) and, being a delta, spans only 34ft. Bearing in mind that no D.H. 110 fully suitable for carrier operation has yet flown, this comparison is more than odious. The world speed record set up less than twelve months ago by a British research aircraft, is already being challenged by deck-landing fighters. Surely this is no time to introduce a subsonic combat aircraft!

WOOD ENGRAVINGS

At the beginning of last year we celebrated our centenary, and in a "Centenary Number," published on January 4, 1956, there were included some reproductions of woodcuts which first appeared in early issues of this journal. The final selection for these reproductions was by no means an easy task. There was such a mass of material at our disposal, and so many old engravings that we would have liked to include in our "Centenary Number." With some reluctance we put them aside, hoping, at the same time, that some opportunity might be found to reproduce more! Our hope, we say with becoming modesty, was quickly echoed by a host of friends. With their expressions of appreciation before us, we decided that in the normal weekly issues during our centenary year, there should be reprinted further selections of our wood engravings.

In the series, which began in the issue of January 20 and continued until December 28, 1956, no less than 140 of these wood engravings were reproduced. They were selected from volumes of this journal published in the twenty-five-year period, 1856 to 1881. It was a period of many inventions, and a period during which engineering development of one kind and another was by no means inconsiderable. Taken together, the engravings make an interesting pictorial addition to the engineering history of a significant part of the nineteenth century. The variety of the subjects covered by the engravings is alone sufficient to emphasise that a hundred years ago, as now, there were few departments of everyday life which were not influenced in some way or other by the work of engineers. To take some of the engravings at random there are those illustrating beam engines, locomotives, traction engines, machine tools, bridges and other civil engineering works, ships, agricultural machinery, clock motions, scientific laboratories, fire-engines, and ordnance. There are others relating specifically to matters which attracted a good deal of public attention in the second half of last century. These included proposals for the removal of Temple Bar from the point at which Fleet Street runs into the Strand, and also the question of a permanent site for the erection of Cleopatra's Needle. Both were matters which this journal stoutly advocated could be decided by engineers. The schemes which we devised were illustrated by some very attractive wood engravings. Who can now say that two of London's well-known landmarks would not have been more effectively displayed had our suggestions proved acceptable to the powers that be!

But fascinating and instructive as the subjects of the old engravings are, the art and craftsmanship revealed in the preparation of woodcuts are eminently worthy of recollection. Box wood, we believe, was always used, the pieces of which were limited in dimension. Several small blocks of the wood had, therefore, frequently to be fitted together before making a large engraving. Upon the block or blocks of box wood the picture and any required lettering had to be drawn "in reverse." Then, every space between the lines, no matter how minute, had to be cut away. The result was the negative from which a positive impression was gained. When the wealth of detail so clearly delineated in many of these old illustrations is studied, some idea can be formed of the prodigious amount of work that was accomplished, accurately and often at great speed, by those who were engravers upon wood. It was work which represents craftsmanship of a high order. We would not, for a moment, suggest that such craftsmanship has not been repeated in the half-tone and line processes which, by the end of last century, had virtually superseded wood engraving for illustrating journals such as ours. Far from it, for we know well that in the more modern processes the work of both artist and craftsman is revealed. But we are nevertheless happy that we have found an opportunity, in reproducing some of our early engravings, to recall the elegance of technical illustration in days now past. The pleasure that we have derived from the exercise is a pleasure which we are proud to know has been shared by many.

A Seven Day Journal

I.E.E. Honorary Membership and Faraday Medal

THE Institution of Electrical Engineers has elected Sir Noel Ashbridge, one of its past-presidents, to honorary membership, in recognition of his distinguished services to the Institution and of his outstanding contributions to radio engineering, particularly in the development of the British sound and television broadcasting services. Sir Noel worked for six years with Marconi's Wireless Telegraph Company, Ltd., at the Writtle experimental station before joining the B.B.C. in 1926 as assistant chief engineer. In 1943, he became deputy director-general of the B.B.C., and in 1948 he became director of its technical services. Sir Noel was knighted in 1935 for his services to British broadcasting. Previously the honour of Knighthood of the Royal Order of Dannebrog had been conferred upon him for his part in the setting up of the Danish broadcasting system. The Institution of Electrical Engineers has also elected to honorary membership Brigadier-General Sir Harold Hartley, in recognition of his life-long interest in all aspects of engineering science and in the conservation of natural resources, an interest which was epitomised in the first Graham Clark Lecture in 1955, on the engineer's contribution to the conservation of natural resources. Sir Harold Hartley was president of the British Association for the Advancement of Science in 1956, chairman of the World Power Conference in 1935–1950, and president of the Conference since 1950. He has twice been president of the Institution of Chemical Engineers. The thirty-fifth award of the I.E.E. Faraday Medal has been made to Carl Borgquist, for his outstanding work on the development of electricity supply and transmission, particularly at extra-high voltages, and for his devotion to the education and training of engineers. For nearly forty years he was intimately concerned with electrical power developments, from his appointment as plant engineer at Trollhättan power station in 1908, until his retirement from the Swedish State Power Board, in 1947, after having served, in turn, as chief engineer, director, and director-general. Dr. Borgquist has played an outstanding part in the development of a.c. power transmission at extra-high voltages, and in the inauguration of the work which culminated in the 100kV d.c. submarine power cable between the island of Gotland and the Swedish mainland.

Broadened Basis of British Nuclear Energy Conference

THE membership of the British Nuclear Energy Conference is to receive welcome reinforcement as a result of the recent decision to admit as members the Iron and Steel Institute and the Institute of Metals. It will be recalled that the purpose of the British Nuclear Energy Conference is to co-ordinate the activities of its constituent members in the field of nuclear energy by holding meetings and by publishing a journal. It provides a forum in which scientists and engineers can discuss developments of common interest, in the technologies of nuclear energy. The original constituent members of the Conference were the Institutions of Civil, Mechanical and Electrical Engineers, the Institute of Physics, and the Institution of Chemical Engineers. Metallurgical interests were not, at first, directly represented, but now, with the admission of the Iron and Steel Institute and the Institute of Metals to broaden and strengthen the membership, the Conference becomes better equipped to contribute to the development of nuclear power.

Colliery Mechanisation

LAST Monday, Mr. James Bowman, chairman of the National Coal Board, reviewed the Board's principal activities during 1956.

The Engineer
100 Years Ago
(JANUARY 16, 1857)

"WHAT ARE WE TO DO WITH OUR STREET TRAFFIC?"

"We are assuredly a slow moving people when any new thing is to be done, and very slow to improve upon old things. Even in the face of palpable and useful examples we fail to act upon them till we see them before our eyes, with the spirit of competition to stir our commercial energy, and then we usually act by most absurdly overdoing the matter. It is a very difficult thing to start a new railway undertaking, but not at all difficult to start two or three competing ones.

"And even thus, no doubt, we shall find it when the first street or suburban railway shall be put in operation in this Kingdom, similar to those which have existed for many years in the chief cities of the United States, and thence imported to the suburbs of Paris. If these street railways in any way interfered with ordinary traffic or the passage of other vehicles, the difficulty would not be easy to get over; but experience has shown that no such difficulty exists. The economy is so obvious, that it is marvellous how the system has been so long in abeyance in London and its environs. It is equivalent to multiplying one horse by four, whilst making a road capable of being maintained at about one-fourth of the expense of ordinary pavement or McAdam. The idea of a railway in a street at first startles those unaccustomed to the idea, as an infallible mode of running over passengers; but the fact is that the railway provides and necessitates a special path for the omnibus or carriage travelling in it, and at once effects the means of enabling the passengers to keep out of the way. And with regard to speed, the facility of using breaks on the rails renders stoppage in emergency much more easy than the pulling up with horses.... Our friend, Mr. W. Bridges Adams, whose inventive faculties seem never dormant, has just specified two plans for the construction of street railways."

In the course of that review he commented on mechanisation at the coal face, saying that last year there was "substantial progress" in the introduction of power loading machinery. About 35,000,000 tons of coal (raised and weighed) were mechanically loaded during the year, an increase of nearly 50 per cent over 1955 and seven times as much as in 1947. By November, the proportion of coal power-loaded had reached 18 per cent. Mr. Bowman referred also to the reconstruction department which the Board established last year at its headquarters to take over from those officials responsible for current production the work involved in the heavy investment programme. Capital invested in coal mining, he added, took a long time to produce returns. If it were possible to reduce the time needed to bring a completely new colliery into full production, there would be benefits, not only from increased output at an earlier date, but also from the quicker return on investment. But, Mr. Bowman said, some of the most important development schemes had been delayed because of the shortage of technicians. He added that recently about forty mining students and lecturers from a Hungarian university had come to this country and had asked for employment in the British coal industry. Representatives of the Board had also visited Western Germany and discussed with representatives of the mining industry and the universities there the possibility of recruiting young mining graduates to spend three years in this country in junior positions on the planning staffs. As a result, it had been decided to recruit up to about forty German graduates in the next three years, and it was possible that qualified people from other Continental countries would likewise be recruited. Their employment, Mr. Bowman observed, would enable some of the Board's planning engineers to concentrate on those aspects of reconstruction schemes which required greater experience.

British Railway Accidents in 1955

THE annual report on the accidents which occurred on the railways of Great Britain during the year 1955 has just been issued. It shows that in the year under review the total number of casualties to passengers, railway servants and other persons from all causes was 319 killed and 23,680 injured. Of these totals Class I train accidents caused the death of 40 passengers, 8 railway servants and 11 other persons. The number of these train accidents in the year under review was 1156 as compared with 1197 the previous year, and included 202 level crossing accidents, 392 collisions, and 205 derailments. They accounted for the death of 40 passengers in three collisions—at Leeds City, Barnes and Luton—and 3 derailments—at Sutton Coldfield, Wormit and Milton. In movement accidents, 49 passengers were killed and 4324 injured, the principal causes being misadventure, carelessness and misconduct on the part of the passengers themselves. Although the number of movement accident fatalities to railway servants totalled 154 as compared with 138 the previous year, the total number of casualties at 2152 for the year was a low record. The number of movement accidents to other persons showed an increase on the previous year at 26 fatalities and 47 injuries. In 21 of these accidents pedestrians were struck by railway vehicles at level and footpath crossings. Non-movement accidents during the year showed a decrease as compared with 1954, there being 31 fatalities compared with 40, and 815 fewer injuries at 16,395. An analysis of the primary causes of the 1156 Class I train accidents shows that human failure on the part of the operating staff accounted for 583 of the accidents, and technical defects in which human failure was in some part responsible caused 140 accidents. A point of interest in the final conclusions of Lieut.-Colonel G. R. S. Wilson, who is responsible for the report, is that only one passenger was killed for every 38,000,000 passenger journeys on the railways of the country in 1955, and in all movements by rail the fatalities, including passengers, railway servants and other persons, were 0·7 per 1,000,000 train-miles.

Hydrodynamic Lubrication of Piston Rings and Commutator Brushes

By W. LEWICKI*

No. I

The centrally loaded mode of lubricated sliding has, often in the past, been confused with parallel sliding. In fact, it is convergent, but physically and analytically quite unlike the familiar type, where the load is deliberately offset to cause convergence. At the same time, the mechanism of friction and film-forming action is quite unlike parallel sliding. For one thing, its deviation from parallelism is quite small, the film ratio is, say, 1·02 as against 1 for the parallel mode. Considering that the film thickness is at most 0·001 of the span of the fluid wedge, the small deviation can hardly be expected to be detectable, even by such sensitive methods as, for instance, Newton's fringes. The analysis reveals, nevertheless, that the minute convergence is responsible for something like 100-fold increase in film thickness in comparison with the strictly parallel mode, and a similarly decreased friction. Because the convergence required to do this is so small, clearly, it can develop spontaneously even if the sliding part is held quite "rigidly," say, by elastic deformation of the surfaces between which the fluid is entrapped. It is found that the new mechanism of lubrication can be expressed by unexpectedly simple algebraic formulæ, making it easy to handle and apply the whole theory to practical ends.

BEFORE going into the analysis it will be useful to say a word about its possible applications in engineering, and where it comes beside the theory of strictly parallel sliding.†‡ For piston rings, commutator brushes, and such like sliding or reciprocating parts of machinery, the theory described below is an improvement on the parallel sliding theory. It enables us to find truer thicknesses of the lubricant film and predicts friction much more in line with experience. For relatively light loads or smooth surfaces it should work very well with the atmospheric air as lubricant. Nevertheless, the parallel sliding theory, which is important for fundamental purposes, can still find a field of application in engineering, namely, in those (perhaps rare) cases where the external load is deliberately applied ahead of the halfway point. For parts with a rectangular underface which slide squarely (not askew or obliquely) this theory demands that, in order to cause a steady-state parallel sliding, the load should be applied at one-third of the width of the underface counting from its leading edge (the one at which the lubricant piles up). However, with "dry" friction, when there is practically no other lubricant than the atmospheric air, the experience shows that something very much like the strictly parallel sliding does take place even with the centrally loaded slider. No doubt the minute surface asperities, together with the numerous particles of wear-debris and such like inclusions carried on the surfaces do help in keeping an overall parallelism. It seems, however, that the real clue in this case is the collective action of the surface asperities as individual facets or plateaux. Formally speaking, however, we are not now concerned with the hydrodynamic flow under the conditions of such a high load where the surface asperities come into prominence as individual sliders.

First of all, a general solution for the convergent mode of hydrodynamic sliding is deduced, in a form somewhat similar to the disputed Reynolds solution. It is then shown how it gives rise to the parallel slider solution, on the one hand, and to the centrally loaded slider solution on the other, in an unexpectedly simple form. Consider the geometrical scheme of the convergent slider (Fig. 1). The slider is fixed in space, so that its underface b units in length is at a small arbitrary angle γ to the "moving plane" $0-x$, at a fixed distance h_0 and h_i as shown in the figure. The leading face of the slider is

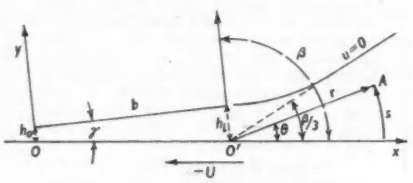

Fig. 1

the solid part of the radius $\theta=\beta$ issuing from the subsidiary origin 0′. The angle β is arbitrary within the condition $\gamma\leqslant\beta<180$ deg., with the analysis possibly remaining a fairly good approximation in the range 180 deg. $\leqslant\beta\leqslant360$ deg. The case $\beta=180$ deg. is that of an ideal semi-plane sliding over an unlimited plane in parallel and the $\beta=360$ deg. case is that of two semi-planes with their edge coinciding. The common case $\beta=90$ deg. is called the square-faced slider. The plane $0-x$ moves with the velocity $-U$ as shown with an arrow. The slider and the plane are ideally smooth, true and rigid, both sufficiently large in all directions to make the transverse flow (in the z-direction) negligibly small in comparison with the two-dimensional flow in the $x-y$ plane. The whole is surrounded to "infinity" with the constant-viscosity fluid. The viscosity (η) is assumed to be sufficiently large to make all body forces within the fluid (gravity, inertia) negligibly small in comparison with the viscous drag. The shear rate is supposed to be not in excess of its limit beyond which the Newtonian law of viscous drag does not apply. In order to maintain the validity of the two one-dimensional approximations in the following analysis, it is generally assumed that

$$\alpha=\frac{h_i}{h_0}>1\ ;\ \gamma\leqslant\beta\ ;\ \frac{h_0}{b}<0{\cdot}01\ ;\ \gamma=\frac{(\alpha-1)h_0}{b}<0{\cdot}01 \quad . \ . \ . \ . \ . \ (1)$$

where h_0 denotes the minimum film thickness, b is the length of the underface of the slider in the direction of motion, γ is called the angle of film convergence, and β the leading angle of the slider. The leading edge of the slider underface ($h=h_i$) and the trailing edge ($h=h_0$) are supposed to be straight, parallel to the moving plane and both perpendicular to the direction of motion. First of all, consider the region of flow under the slider. Like Reynolds in 1886 and Rayleigh in 1918, we use the one-dimensional form of Navier's dynamical equation of viscous flow

$$\frac{\partial^2u}{\partial y^2}=\frac{1}{\eta}\left(\frac{\partial p}{\partial x}\right) \quad . \ . \ . \ . \ (2)$$

where u is the local velocity of flow and p is the pressure at the same point within the fluid. Since the viscosity η is assumed to be constant throughout all regions of the flow, and $(\partial p/\partial x)$ is independent of y everywhere, we have

$$u=-(h-y)\left\{\frac{y}{2\eta}\left(\frac{\partial p}{\partial x}\right)+\frac{U}{h}\right\} \quad . \ . \ (3)$$

as $u=0$ at $y=h$ and $u=-U$ at $y=0$. The flux, i.e. total volume of the fluid per unit width in the z direction crossing any $x=$constant surface in a unit time, is

$$q=\int_0^h u\,dy=-\frac{h^3}{12\eta}\left(\frac{\partial p}{\partial x}\right)-\frac{Uh}{2} \quad . \ . \ (4)$$

Denoting by h_m the film thickness at the point where $(\partial p/\partial x)=0$ and $p=$maximum,

$$q=-\frac{Uh_m}{2} \quad . \ . \ . \ . \ (5)$$

Turning now to the region of the inflow zone (to the right of the leading face in Fig. 1), we apply the one-dimensional "polar" approximation as in the theory of parallel sliding.† With the help of this approximation Navier's dynamical equation becomes

$$\frac{\partial^2u}{\partial s^2}=\frac{1}{\eta}\left(\frac{\partial p}{\partial r}\right) \quad . \ . \ . \ . \ . \ (6)$$

where u is the radial velocity at an arbitrary point $A(\theta, r)$ of Fig. 1, r is the radial distance from the subsidiary origin 0′, and s is the $r=$constant arc, such that $ds=rd\theta$. As has been shown before, equation (6) can be directly integrated with respect to s. When this is done,

$$u=-(\beta r-s)\left\{\frac{s}{2\eta}\left(\frac{\partial p}{\partial r}\right)+\frac{U}{\beta r}\right\} \quad . \ . \ (7)$$

since $u=0$ at $s=r\beta$ and $u=-U$ at $s=0$. Therefore, throughout the inflow region,

$$q=\int_0^{\beta r}u\,ds=-\frac{\beta^3r^3}{12\eta}\left(\frac{\partial p}{\partial r}\right)-\frac{U\beta r}{2} \quad . \ . \ (8)$$

Eliminating q by (5), solving for $(\partial p/\partial r)$ and integrating with respect to r, we have

$$p=\frac{6\eta U}{\beta^3}\left(-\frac{h_m}{2r^2}+\frac{\beta}{r}\right) \quad . \ . \ . \ (9)$$

since $p=0$ at $r=\infty$. Putting $p=p_i$ when $r\beta=h_i$, $h_i=\alpha h_0$,

$$p_i=\frac{6\eta U}{\alpha\beta h_0}\left(1-\frac{h_m}{2\alpha h_0}\right) \quad . \ . \ . \ (10)$$

Returning now to the underface of the slider, we replace q in (4) by (5), solve for $(\partial p/\partial x)$ and integrate with respect to x. Applying the boundary conditions, $p=0$ at the trailing end of the underface, i.e. at $h=h_0$, and $p=p_i$ at its leading end $h=h_i$, we obtain

$$p=\frac{3\eta Ub}{(\alpha-1)h_0^2}\,\frac{(h-h_0)\{(h+h_0)H-2h\}}{h^3} \quad . \ (11)$$

where

$$H\equiv\frac{h_m}{h_0}=\frac{2\alpha(1+h_0/\beta b)}{\alpha+1+h_0/\beta b} \quad . \ . \ . \ . \ . \ . \ (12)$$

By putting also $Y\equiv h_m/h_i$ this can be rewritten more concisely in the following manner:

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* Department of Chemical Engineering, Imperial College of Science and Technology, London. The work described in this article has been done in association with the physics department, Birkbeck College.

† W. Lewicki, "Theory of Hydrodynamic Lubrication in Parallel Sliding," THE ENGINEER, December 30, 1955, pages 939–941.

‡ W. Lewicki, "Is Hardy's Boundary Lubrication a Myth?" *Engineering*, November 18, 1955, page 685.

TABLE I—*The relative increase in the load carried by the slider due to convergence in comparison with the parallel slider. Put $\beta=\pi/2$ for the square-faced slider*

$\alpha=$	1	1·01	1·1	1·5	2·0	2·5	3·0	4·0
$h_0/\beta b=0{\cdot}02$ ...	1	1·17	2·45	5·38	6·24	6·13	5·73	4·83
$h_0/\beta b=0{\cdot}002$ ...	1	2·64	15·4	44·7	53·9	53·4	50·1	42·6

TABLE II—*Relative increase of the load carried due to convergence in comparison with Reynolds' solution*

$\alpha=$	1	1·001	1·01	1·1	2·0	3·0
$h_0/\beta b=0{\cdot}02$ ...	∞	60·5	6·78	1·69	1·17	1·15
$h_0/\beta b=0{\cdot}002$ ...	∞	7·00	1·57	1·07	1·02	1·02

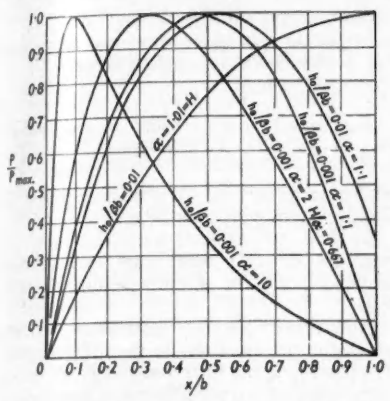

Fig. 2—Numerical examples of pressure distribution

$$p=\frac{3\eta Ub}{(\alpha-1)h_0^2}\,\frac{(H-1)^2-(Y-1)^2}{H} \quad . \quad . \quad (13)$$

Note that $Y=H$ at $h=h_0$ and $Y=H/\alpha$ at $h=h_i$. In the latter case, equation (13) gives

$$p_i=\frac{6\eta U}{\alpha\beta h_0}\left(1-\frac{H}{2\alpha}\right)=\frac{6\eta U}{(h_0\beta(\alpha+1+h_0/\beta b)} \quad . \quad (14)$$

At $Y=1$, evidently, the pressure is at its maximum

$$p_m=\frac{3\eta Ub}{(\alpha-1)h_0^2}\,\frac{(H-1)^2}{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

The explicit pattern of pressure under the slider is obtained from

$$\frac{p}{p_m}=1-\left(\frac{Y-1}{H-1}\right)^2=1-\left(\frac{1-x/x_m}{1+(\alpha-1)x/b}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad (16)$$

where the distance of the pressure maximum from the narrower end of the underface is

$$\frac{x_m}{b}=\frac{H-1}{\alpha-1}=\frac{1+\left(\frac{2\alpha-1}{\alpha-1}\right)h_0/\beta b}{\alpha+1+h_0/\beta b} \quad . \quad . \quad . \quad (17)$$

Some numerical examples of the pressure distribution (16) are shown graphically in Fig. 2. Note that p_m occurs right at the leading edge ($h_m=h_i$) when

$$H=\alpha, \text{ i.e. } \frac{h_0}{b}=(\alpha-1)\beta \quad . \quad . \quad (18)$$

For lesser film thicknesses h_0 the pressure maximum is within the underface region and for higher values of h_0 it must be somewhere along the leading face. We then put $h_m=\beta r_m$. Equation (18) is subject to the condition $h_0/b\leqslant 0{\cdot}01$. Taking that β is, ordinarily, commensurate with unity, it follows that (18) is only valid for film ratios α quite close to unity. The explicit patterns of flow for the underface and the inflow regions are obtained by replacing $(\partial p/\partial x)$ in (3) and $(\partial p/\partial r)$ in (7) by the respective pressure gradients. For the region under the slider we obtain

$$u=\left(1-\frac{y}{h}\right)\left\{\frac{3y}{h}(1-Y)-1\right\}U \quad . \quad . \quad (19)$$

and for the inflow region,

$$u=\left(1-\frac{s}{\beta r}\right)\left\{\frac{3s}{\beta r}\left(1-\frac{r_m}{r}\right)-1\right\}U \quad . \quad . \quad (20)$$

where $r_m=h_m/\beta$ if p_m occurs under the slider. A specific example, Fig. 3, shows the two patterns jointly. The inflow region pattern is of particular interest since it represents the only observable part of flow in direct experiments. The shape of the $u=0$ contour crossing the inflow region is, evidently,

$$\frac{s_0}{r}=\frac{\beta}{3(1-r_m/r)} \quad . \quad . \quad . \quad . \quad (21)$$

where s_0/r is the angle which the vector radius r from 0′ (Fig. 1) to a point along the $u=0$ curve makes with the moving plane. When $r\to\infty$, $s_0/r\to\beta/3$. This direction and the overall shape by (21) are very much as observed in the fluid bath and elastic plate experiments (see the leading paragraph of "Conclusions"). We now turn to the problem of the external load carried by the slider. Its resolute in the direction normal to the underface of the slider, N units of force per unit length of the underface in the z-direction is, by (13),

$$N=\int_0^b p\,dx=A^1\frac{\eta Ub^2}{h_0^2} \quad . \quad . \quad . \quad . \quad . \quad (22)$$

where

$$A^1\equiv 6\left\{\frac{ln\alpha}{(\alpha-1)^2}+\frac{H}{2\alpha}-\frac{1}{\alpha-1)}\right\} \quad . \quad (23)$$

As is easily verified, N has a maximum with respect to α (i.e. when the factor $\eta Ub^2/h_0^2$ is kept constant) at about $\alpha=2$, the exact value of α depending on the value of h_0/b or, by (22), on the ratio $N/\eta U$. Incidentally, it would perhaps be appropriate to call the latter ratio the non-dimensional load; its reciprocal, $\eta U/N$, would thus become the non-dimensional sliding velocity. By putting $\alpha=1$ in (22), (23), they can easily be shown to reduce to

$$N_{\alpha=1}=\frac{3\eta Ub}{h\beta(2+h/\beta b)} \quad . \quad . \quad (24)$$

as previously found for the parallel slider. The effect of α on N can be seen from Table I, giving some values of the ratio $N/N_{\alpha=1}$.

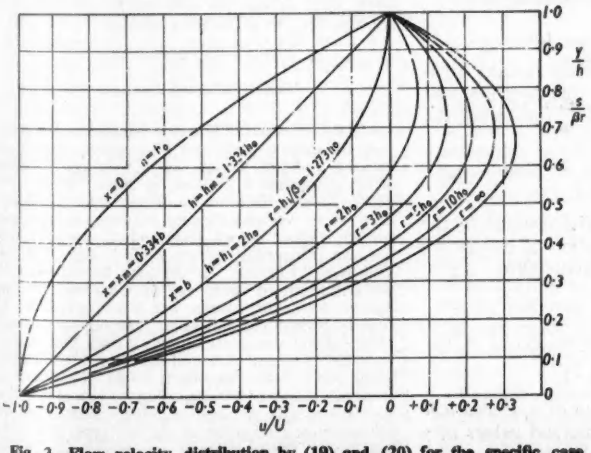

Fig. 3—Flow velocity distribution by (19) and (20) for the specific case $h_0/\beta b=0{\cdot}001$, $\alpha=2$, $\beta=\pi/2$. At the radial distance $r=10h_0$ i.e. five times the inlet gap, the velocity distribution is already approaching the pattern characteristic of infinite distances

It may also be interesting to compare the present results with corresponding Reynolds' solutions :

$$p=\frac{6\eta Ub}{h_i^2-h_0^2}\left\{\frac{(h_i-h)(h-h_0)}{h^2}\right\} \quad . \quad (25)$$

$$N=\frac{6\eta Ub^2}{h_0^2}\left\{\frac{ln\alpha}{(\alpha-1)^2}-\frac{2}{\alpha^2-1}\right\} \quad . \quad (26)$$

Some cross-section values of the ratio N_{22}/N_{26} are given in Table II. Note that Reynolds' solution for N is a fairly good approximation for relatively heavy loads, except for small convergencies.

It is evident from Table II that the analysis of the centrally loaded case could have been in terms of Reynolds' solution with a fair measure of success, but no one in the past seems to have noticed that a distinction between the parallel and centrally loaded sliding should be made (see further text for the case of centrally loaded slider). We now turn to the question of film thickness. On putting the value of $H=h_m/h_0$ from (12) into (23) we obtain from (22) the equation

$$\left(\frac{h_0}{b}\right)^3+\beta(\alpha+1)\left(\frac{h_0}{b}\right)^2-\frac{6\eta U}{N}\left\{\frac{ln\alpha}{(\alpha-1)^2}-\frac{2-\alpha}{\alpha-1}\right\}\left(\frac{h_0}{b}\right)-\frac{6\beta\eta U}{N}\left\{\frac{(\alpha+1)ln\alpha}{(\alpha-1)^2}-\frac{2}{\alpha-1}\right\}=0 \quad . \quad . \quad (27)$$

from which h_0/b can easily be found as a function of the non-dimensional sliding velocity ($\eta U/N$), α and β. When β is large, such as $\beta=\pi/2$, an approximate solution of (27) evidently is

$$\frac{h_0}{b}=A_2\sqrt{\frac{\eta U}{N}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

where

$$A_2^2\equiv\frac{6}{(\alpha-1)}\left\{\frac{ln\alpha}{\alpha-1}-\frac{2}{\alpha+1}\right\} \quad . \quad (29)$$

which are precisely Reynolds' solution. For the square faced slider ($\beta=\pi/2$) a good agreement with (27) is obtained when

$$\frac{h_0}{b}<0{\cdot}01, \quad \frac{\eta U}{(\alpha-1)N}<0{\cdot}001 \quad . \quad . \quad (30)$$

For instance, at $\eta U/(\alpha-1)N=10^{-3}$ the value of h_0 by (27) is $1{\cdot}022h_0$ by (28) at $\alpha=1{\cdot}01$ and $1{\cdot}1$, increasing to $1{\cdot}032h_0$ at $\alpha=2$. Again, at $\eta U/(\alpha-1)N=10^{-4}$ the ratio is $1{\cdot}008$ at $\alpha=$ $1{\cdot}01$ and $1{\cdot}1$. With these limitations in mind the coefficient A_2 can be used to compute h_0/b from (28). Some numerical values of A_2 by (29) are given in Table III.

TABLE III—*Values of A_2 by (29) for the square-faced slider ($\beta=\pi/2$). Limitations for the use of A_2 are given in the text*

α	A_2	α	A_2
1·01	0·0702	2·5	0·3972
1·05	0·1524	3·0	0·3846
1·1	0·2080	4·0	0·3524
1·5	0·3622	5·0	0·3218
2·0	0·3986	10·0	0·2221

We now turn to the question of the centre of pressure. Even though the film ratio α may be large in comparison with unity, the convergence angle γ is, ordinarily, very small —say, 5 minutes of arc. Consequently, elastic deformations, &c., would make it very difficult (if not impossible) to preset the angle directly ; that is to say, in a rigid manner. This difficulty can be overcome with the help of some such constructional arrangement as that shown in Fig. 4.

The external load N is converted into a

TABLE IV—*Values of* ε *in the distance* εb *of Fig.* 4 *by equation* (31), *required to cause the sliding at a given film ratio* α, *when the ratio* $h_0/\beta b=0{\cdot}002$. *For the square-faced slider put* $\beta=\pi/2$. *Broadly speaking, these values are representative of moderately heavy loads*

$\alpha=$	1·0	1·01	1·1	1·5	2·0	2·5	3·0	4·0
$\varepsilon=$	0·333	0·438	0·496	0·537	0·566	0·587	0·605	0·630

TABLE V—*Values of* ε *in the distance* εb *of Fig.* 4 *according to the disputed Reynolds' solution* (33). *Note that the centrally loaded slider appears to be truly parallel. Correct values of* ε *are given in Table* IV

$\alpha=$	1·0	1·01	1·1	2·0	3·0	4·0
$\varepsilon=$	0·500	0·501	0·510	0·569	0·608	0·633

TABLE VI—*The coefficient of friction* μ *by* (37) *for the square-faced slider with an ideally sharp leading edge. The film thickness* h_0 *is kept constant as shown while the load* N *varies with* α *by* (22). *This table does not apply to round or obliquely moving sliders*

$\alpha=$	1·0	1·01	1·1	1·5	2·0	2·5	3·0	4·0
$h_0/\pi b=0{\cdot}01$ ...	1·047	0·930	0·426	0·174	0·140	0·136	0·141	0·139
$h_0/\pi b=0{\cdot}001$ ...	1·047	0·396	0·065	0·020	0·015	0·014	0·015	0·016

TABLE VII—*Values of* μ *by* (37) *for the square-faced slider. The load is kept constant at* $N/\eta U=10^6$. *The film thickness* h_0 *varies with* α *by* (27)

$\alpha=$	1·01	1·05	1·1	1·5	2·0	2·5	3·0	5·0
$\mu=$	0·0141	0·0064	0·0045	0·0023	0·0019	0·0018	0·0018	0·0019

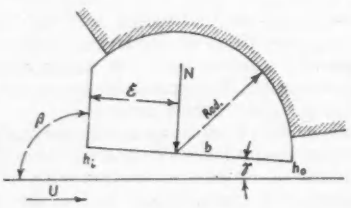

Fig. 4

concentrated force, in effect acting at the surface delimiting the fluid wedge, at a preset distance from its leading end. In this manner the fluid drag (tangential force) acting on the underface of the slider is made inoperative for the equilibrium magnitude of γ, the latter becoming simply a matter of balance between the moments of the normal forces acting on the underface. For the scheme of Fig. 4 we have, by (12), (13), (22),

$$\varepsilon=\frac{1}{bN}\int_0^b xp\,dx$$

$$=\frac{2(H+2\alpha)\dfrac{ln\alpha}{(\alpha-1)}-(3-\alpha)H-2(\alpha+1)}{4(\alpha-1)\left\{\dfrac{ln\alpha}{(\alpha-1)}+\dfrac{(\alpha-1)H}{2\alpha}-1\right\}} \quad . \quad . \quad . \quad . \quad . \quad (31)$$

giving the distance εb at any desired combination of α, β, and h_0/b. Note that εbN is the moment of N with respect to the leading edge of the slider and the integral is the moment of the fluid pressure on the underface. Note also that the friction between the support and the curved portion of the slider is supposed to be nil. Some values of ε by (31) are given in Table IV, for rather heavy loads. At lighter loads than those indicated in the table the values tend to be somewhat less.

It may be interesting to find the solution of (31) in terms of the disputed classical theory. According to Reynolds,

$$H=\frac{2\alpha}{\alpha+1} \quad . \quad . \quad . \quad . \quad . \quad (32)$$

as is evident from the comparison of (26) with (22) and (23). In effect, Reynolds has put $h_0/b=0$ in the right-hand side of (12). Inserting the result (32) into (31) we obtain

$$\varepsilon=\frac{\alpha(\alpha+2)ln\alpha-(5\alpha+1)(\alpha-1)/2}{(\alpha^2-1)ln\alpha-2(\alpha-1)^2} \quad . \quad (33)$$

Some numerical values of ε according to (33) are given in Table V.

Note the characteristic difference between Tables IV and V in the value of ε at $\alpha=1$. It gives us the clue that the result (33) might have been the stumbling block in understanding the fundamental difference between the parallel and centrally loaded slider. The point is to be borne in mind that ε must be 0·333 quite irrespective of the merits of the proposed solution for the value of p_0, provided that the flow obeys the Newtonian definition of viscosity, and that the viscosity remains constant all along the fluid wedge under the slider.

We now turn to the problem of hydrodynamic friction. Since we are concerned with the underface of the slider and not with the opposed surface of the "moving plane," we presently assume that the slider moves with the velocity U along the stationary plane, as shown in Fig. 5.

Of course, there is no absolute need to use this reversed scheme, since we can compute the tangential drag equally well in either case, except that it is preferable to adjust the analysis to the physical reality for the sake of avoiding mistakes.

The point is that, as a matter of principle, when the slider remains stationary it cannot suffer any frictional loss of energy because it has none to lose. Now, in Fig. 5, the fluid exerts on the underface of the slider the tangential stress

$$\tau=-\eta\left(\frac{\partial u}{\partial y}\right)_{y=h}=\frac{2\eta U}{h}\left(1-\frac{3h_m}{2h}\right) \quad . \quad (34)$$

Hence, the total force of fluid drag over the span of the slider, per unit width in the z direction, is

$$T=\int_0^b \tau\,dx=\frac{2\eta Ub}{h_0}\left(\frac{3H}{2\alpha}-\frac{ln\alpha}{\alpha-1}\right) \quad . \quad (35)$$

Note that T is directed as shown in the figure only for small film convergencies, below a certain value of α at which $T=0$.

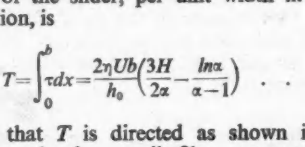

Fig. 5

For larger values of α, T must remain negatively directed. Of course, this does not lead to a negative coefficient of friction, since the latter is not $\mu=T/N$, but

$$\mu=\frac{T+f}{N}=\frac{2\eta Ub}{Nh_0}\left(\frac{3H}{2\alpha}-\frac{ln\alpha}{\alpha-1}\right)+\frac{(\alpha-1)h_0}{b} \quad . \quad (36)$$

where $f=N\gamma$ is the tangential resolute of the normal load N in the direction of motion U. Eliminating N by (22), we finally have

$$\mu=\left\{\frac{\dfrac{2ln\alpha}{3(\alpha-1)}+\dfrac{H}{2}-1}{\dfrac{ln\alpha}{(\alpha-1)^2}+\dfrac{H}{2\alpha}-\dfrac{1}{\alpha-1}}\right\}\frac{h_0}{b} \quad . \quad (37)$$

which, clearly, is a function of α, β and h_0/b alone, by (12). Some numerical values of μ by (37) are given in Table VI, for the square-faced rectangular slider. Note that this table does not apply to such sliding parts whose underface is, for instance, round or square, but moving obliquely.

In order to elucidate somewhat more the meaning of (37) two more cross-section sequences of μ are given in Tables VII and VIII.

Note that (37) is only valid when there are no elastic deformations in the film thickness gradient along the fluid wedge and no surface unevenness of any significance in comparison with the film thickness. Note also that μ has its minimum with respect to α at about $\alpha=2{\cdot}5$, when $h_0=$constant, and at about $\alpha=3$ when $N/\eta U=$constant. It will be remembered that N is maximum with respect to α at about $\alpha=2$. Finally, it may be interesting to see what is the friction along the moving plane in comparison with that of the underface. Assume that the slider is stationary and the plane moving with the velocity $-U$. We find then,

$$\mu=\frac{4\eta Ub}{Nh_0}\left(\frac{ln\alpha}{\alpha-1}-\frac{3H}{4\alpha}\right) \quad . \quad . \quad . \quad (38)$$

which can easily be seen to be slightly less than $(T+f)/N$ by (36) and (37). The cause of this apparent anomaly must be sought in the inflow region. Since, theoretically, the overall friction must be the same in both cases, we conclude that the drag at the moving plane in front of the slider (the inflow region) must be a trifle greater than the components in the direction of motion of the normal and tangential forces at the leading face. It is found to be so, indeed, but the matter need not be related at present since it has no obvious application. The forces on the leading face are ordinarily much too small to have any effect on the load carried and friction for the slider as a whole.

TABLE VIII—*Values of* μ *by* (37) *for the square-faced slider. The film-ratio is kept constant at* $\alpha=3$. *This is approximately the least friction for the slider with* $\beta=\pi/2$

$N/\eta U=$	10^3	10^4	10^5	10^6	10^7	10^8
$\mu=$	0·0578	0·0182	0·0057	0·0018	0·0006	0·0002

(*To be continued*)

MECHANICAL SHAFT SEAL FOR CORROSIVE SERVICES. —A mechanical shaft seal introduced by Crane Packing, Ltd., of Slough, has a main seal member which comprises a bellows of pure "Fluon" to which running faces of glass-reinforced "Fluon" have been welded. Spring loading, to maintain contact between the seal faces and the seat (or seats), has been achieved by using a P.T.F.E. sleeved spring. This new "Fluoseal" is designed for use with all concentrations of acids and salts, strong oxidising agents or reducing agents, and it is also resistant to organic compounds and salts. The normal pressure range for which seals are suitable is from 20in vacuum to 50 lb per square inch, and the normal temperature range from −40 deg. Cent. (−40 deg. Fah.) to +80 deg. Cent. (+176 deg. Fah.). It is stated that the seals may be run dry indefinitely if arrangements are made for dissipation of the heat generated at the seal faces. The seals are at present supplied in sizes for ¾in to 2in diameter shafts, and there are two designs for external and internal mounting, respectively.

Huyghens Tercentenary Exhibition

By T. R. ROBINSON, F.B.H.I.

The most outstanding advance in horology after the invention of the mechanical clock was the introduction by Christiaan Huyghens of the pendulum clock, which raised the clock to the standard of a precision timepiece. An exhibition to mark the tercentenary of this invention is now being held at the Science Museum, South Kensington, and will remain open until February 24. This article deals with some of the exhibits of particular interest.

THE Tercentenary Exhibition of the pendulum clock of Christiaan Huyghens, which was opened at the Science Museum, South Kensington, London, on December 4, by Dr. D. W. Stikker, the Netherlands Ambassador, commemorates the invention that was, undoubtedly, the most important single advance in the science of horology after the introduction of the mechanical clock itself.

The application of the pendulum, with its isochronous characteristic, to the control of timekeeping enabled the standard of accuracy to be raised at one step from terms of hours or half-hours to one of minutes and, for the first time, made the clock a precision instrument.

Christiaan Huyghens, who was born in 1629 at the Hague, was the second son of Constantijn Huyghens, a well-known poet and statesman, and he possessed a brilliant scientific mind. After studying law and mathematics at Leyden University, he went to Breda to carry out further studies for two years, and then returned to the Hague, where he devoted himself entirely to scientific study and experiment for the next seventeen years. The results of his work included the theory of probabilities, the laws of elastic concussion, and of centrifugal force, geometric optics and its application to lens grinding, the discovery of Saturn's ring, and of its satellite, Titan, and of the pendulum clock. He visited London three times, and on the second visit was elected a Fellow of the Royal Society. On his third visit he frequently met Sir Isaac Newton, and there seems to have been a great mutual admiration between the two scientists.

Two other important horological inventions of Huyghens were the balance and spring, which, however, he was never able to construct with sufficient accuracy to make it of real timekeeping value, and the "endless chain" method of clock-weight suspension, so often met with on old thirty-hour long-case clocks, and now almost universally used for automatically-wound tower clocks.

The exhibition at the Science Museum, which has been organised by the museum and the Antiquarian Horological Society in collaboration, will remain open until February 24 next. Although it is comparatively small in size, it is of great significance to all interested in the science of time measurement, for the exhibits have been carefully chosen to demonstrate the complete story of the introduction of the pendulum, and of the developments in precision timekeeping rendered possible by its use.

The first section of the exhibition is, accordingly, devoted to clocks before the application of the pendulum, and includes two Gothic domestic clocks made of wrought iron and fitted with the foliot arrangement of escapement control. The examples are particularly good ones, and show the crudities of these early attempts at timekeeping. In the same section is a remarkable wood-cased clock by Jobst Burgi, made about 1580, and embodying a remontoire mechanism. This is the first known example of this device, which aimed at providing a constant force to the escapement, and was used even after the introduction of the pendulum and until fairly recent times.

There are also some fine specimens of clocks fitted with a cross-beat escapement, a device which sought to cancel out the errors of the foliot by what was, in effect, the use of two. The result was only partially successful, for neither the foliot nor the cross-beat arrangement had any inherent isochronism, and the timekeeping varied considerably with variations in friction and driving force. Faced with this problem, horologists attempted to secure a constant driving force by a number of different methods, such as the remontoire and the constant force ball drive, which is to be seen in the bracket clock by Nicholas Radeloff (Fig. 1). Here a heavy steel ball

Fig. 1—Details of escapement and ball drive of Radeloff clock, 1660

drives the clock by descending the spiral turns of a cage that is connected to the clock movement through a central column. As the ball reaches the bottom of the cage it releases the next ball from a magazine at the top. Another use of balls is illustrated in a photograph of a rolling ball clock, in which two balls traverse a set path in turn. Each ball takes one minute to complete its journey, and during this time the other ball is raised to the top, ready for the next descent. Again, there is no real isochronism and timekeeping is poor.

The real discovery of the isochronal properties of the pendulum was, of course, made by Galileo, and in the next section of the exhibition there is a copy of a sketch of his proposed method of applying it to a clock, Galileo never carried his ideas into effect, but there is shown a model of his escapement which demonstrates the action.

Another exhibit in this section is an Italian chamber clock by Camerini, dated 1656, which has a form of pendulum, and does not seem to have been converted from an earlier foliot arrangement. It may be an anticipation of Huyghens's invention, but it seems that its authenticity is disputed by some authorities.

The other exhibits in this section are drwings and sketches, including one by Leonardo da Vinci, taken from the Codex Atlanticus, and showing a pendulum, apparently attached to a verge. The details of this drawing, and of the others accompanying it in this section, indicate a groping towards the use of the pendulum, but it seems that the technical problems had not by any means been solved at that stage.

With the third section of the exhibition, Huyghens himself comes into the picture. The first exhibit consists of a fine oil painting of recent date, showing Huyghens handling Salomon Coster's pendulum clock in his workshop. The painting, which is by Hugh Chevins, is a fine piece of work, notable for its technical accuracy, and is a copy of the original in the possession of Imperial Chemical Industries, Ltd. It is reproduced in colour on the cover of the exhibition brochure.

The next two exhibits are very interesting indeed, for they are a photograph of Huyghens's own drawing of his pendulum timepiece (Fig. 2), reproduced from his Horologium of 1658, and a modern model, made from this drawing, and shown working. The model illustrated in Fig. 3 is exact in every detail, and is a very fine piece of craftsmanship. Its dial, in accordance with Huyghens's drawing, is rather novel, for it has, on the main dial circle, an hour hand and a hand which rotates once in five minutes, and is read against a chapter ring marked out in tens of seconds. A subsidiary minute hand appearing between the centre of the main dial and the figure VI on the hour circle, rotates once per hour, and its dial ring is divided up into two-minute divisions.

The escapement of this clock is a verge, and it is linked to the pendulum through a right-angled reduction gearing made up of a wheel on the verge pallet arbor and a part-contrate wheel on the crutch arbor. This arrangement embodies a 2-to-1 step-down ratio which enables the pallets to be operated with a pendulum arc of correctly moderate dimensions. The weight drive is by "endless rope," which is identical in principle with the "endless chain," and so the clock shows two of Huyghens's important inventions. The winding of this endless rope is by a ratchet wheel and rope drum located between the dial and the front plate of the clock movement.

Two further exhibits consist of a photograph of Huyghens's own drawing (Fig. 4) of one of his pendulum timepieces, and a reproduction of the clock itself. This clock is fitted with the famous "cycloidal cheeks," which Huyghens devised in an attempt to overcome the cycloidal error, and another feature of the clock is the oddly shaped, almost streamlined, pendulum bob.

By no means all of Huyghens's pendulum inventions were intended for use on domestic clocks, for, behind much of his research was an attempt to construct a clock which could be used to keep time at sea. The problem of determining longitude was very much in the minds of horologists in his time, and he vied with others in efforts to produce a reliable marine timepiece. Such a timekeeper would have been of immense value to naviga-

tion, but it is scarcely surprising that no effective method of using a pendulum for this purpose was ever devised. It seems strange that such a brilliant scientific mind as that of Huyghens's did not perceive the beginning of a solution in his balance and spring, but the difficulties of compensating this invention against temperature variations

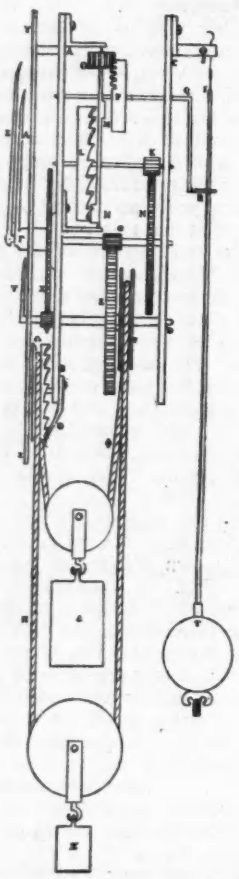

Fig. 2—Huyghens's drawing of his timepiece, 1658

seem to have been so discouraging that work on it was not proceeded with.

The final exhibit in this section is a photograph of a modern reconstruction of Huyghens's marine timepiece with weight remontoire. This is interesting, but it was hardly practical as a timekeeper for use at sea. The actual model is in the Museum of Science, Leyden, Holland, the authorities of which have proved to be most helpful to the organisers of the London exhibition.

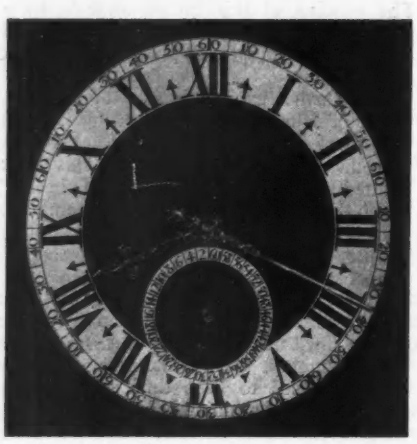

Fig. 3—Modern reproduction of Huyghens's clock of 1658

The principles underlying the operation of a pendulum form the subject of the next section. A very instructive model shows how the periodic time of a pendulum is almost independent of its arc for small arcs, but varies when larger arcs are described unless corrected by cycloidal cheeks. This model can be operated by visitors, for the pendulums are energised electrically. A novel exhibit is an illustration of Hooke's experiment designed to show that a long pendulum with a heavy bob can be maintained in motion by a very small force. In it, a long pendulum is linked to an old verge watch movement, the energy transmitted through the balance of which is ample to keep the pendulum swinging through a small arc.

A collection of early pendulum clocks which has been assembled is one of the most interesting parts of the exhibition. Some of the clocks are from Holland and Belgium, but two by famous English makers, Fromanteel and Hilderson, are very fine examples. The Fromanteel long-case clock illustrates the improvement in timekeeping achieved by the middle of the seventeenth century in a very distinctive way, for it is fitted with a " maintaining power," or device to keep the timekeeping train running during the time that the clock is being wound. Such a fitting is only necessary when the clock concerned is a fairly precise timekeeper, and in the pre-pendulum period the error introduced by the time of winding would have been too small to take account of. The Hilderson bracket clock has a novel detail in its striking mechanism, for it repeats the striking of each hour on a smaller bell at the following half-hour, and this is done by the same hammer that sounds the hour, but on another bell, this second, smaller bell being arranged to move in front of the hammer for the half-hour. With the approach of the next hour, the larger bell returns to the point where it can be struck, and the smaller bell moves aside.

Other clocks include a fine German wall clock, shown in Fig. 5, which has a pendulum swinging in front of its dial ; and two French clocks, one a wall timepiece by Thuret, of Paris, which is clearly modelled on Huyghens's design, and may even have been in his possession, for it has been in Leyden since the early eighteenth century. It is weight-driven, has the Huyghens endless cord to support its weight, and its seconds pendulum is fitted with cycloidal cheeks. The other French clock is a bracket clock and is by Isaac Thuret, who was probably the same maker as the Thuret mentioned above. One mainspring drives both the timekeeping and striking parts of this clock, and this may be the first example of a method that has often been used since then.

The development of the pendulum clock from the end of the seventeenth century to the present day is illustrated by a group of clocks which includes a very fine long-case clock by William Clement, a famous maker to whom the invention of the recoil escapement is sometimes attributed. This clock has a 1¼-second pendulum, which is fitted with a kind of micrometer adjustment for accurate regulation, another evidence of the increasing precision in timekeeping of which clocks were becoming capable.

Another long-case clock is by the famous George Graham, inventor of the dead-beat escapement. It is fitted with the dead-beat escapement, and shows very well the increased freedom to the pendulum afforded by the maker's invention. Research had demonstrated that the secret of improved timekeeping from a pendulum lay in minimising any interference with its swing, and the whole of the subsequent design of escapements took place along these lines. This example is a very important exhibit, for it shows an escapement that became the standard for precision clocks for over 200 years, and is still much in use to-day, being used for industrial clocks, such as time-recorders, as well as for many domestic clocks.

One exhibit in this group, which is illustrated in Fig. 6, is probably the finest mechanical clock ever made. It is a regulator by Dent, and was made in 1872. It is lent by the Royal Observatory, Hurstmonceaux, and was the Observatory's principal sidereal standard timepiece from 1872 until it was superseded by a Shortt Free Pendulum clock in 1925. Its escapement, designed by the famous Sir John Airy, Astronomer Royal, is a modification of the chronometer detent escapement, adapted to a pendulum. The pendulum itself is fitted with zinc-steel

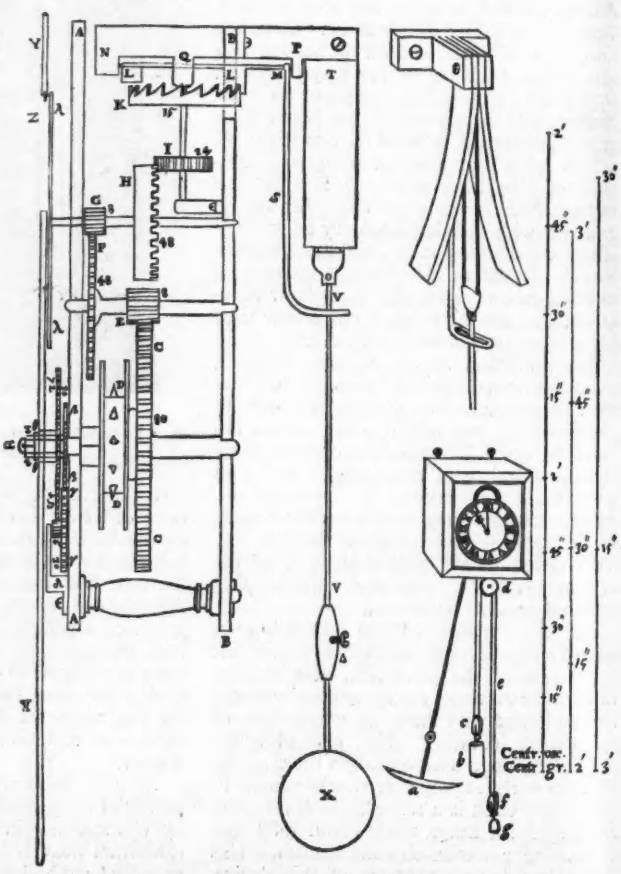

Fig. 4—Huyghens's drawing of his timepiece, 1673

temperature compensation, and is also provided with a barometric compensation device. The rate of this clock varied only a few hundredths of a second per day. The workmanship throughout is of the very highest class, and the exhibition is well worth while visiting to see this clock alone.

The final stage in pendulum clock development is illustrated by a fine Shortt Free Pendulum clock, loaned by the Synchronome Company, Ltd. This is really a dual clock, for there are two separate mechanisms, electrically linked. The principle of operation, which is distinctly novel, is the ultimate refinement of the attempt to remove all possible sources of interference from the swing of a pendulum. On the Shortt clock this is done by using two pendulums, one being the "master" and the other the "slave." The master, or "free" pendulum, is housed in an airtight casing, and runs in a high degree of vacuum. It does not operate any mechanism, and only receives its maintaining impulse every half-minute. The impulse is given by a small gravity arm, which is electrically released by the slave clock every thirty seconds, and then falls by gravity, delivering its impulse to the master pendulum by means of an inclined plane fitted to the pendulum rod. Having given its impulse, the arm falls off the inclined surface on the free pendulum rod, and in descending slightly further, completes a circuit which not only energises an electromagnet that replaces the gravity arm, but also synchronises the slave pendulum with the free pendulum. In this way, the slave pendulum is kept in perfect step with the

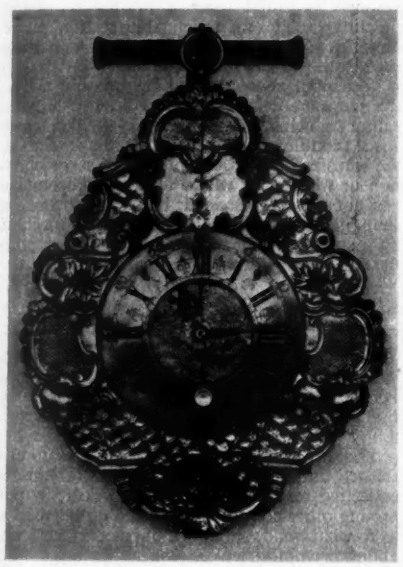

Fig. 5—The pendulum of this German wall clock swings in front of the dial and its bob can be seen over the hour numeral VI

master without the master having to do anything beyond the reception of its maintaining impulse. The slave pendulum is that of a half-minute design electric clock that is very similar to those used to drive the impulse dial circuits in large buildings, but has the additional mechanism necessary for its synchronism with the master clock pendulum. This form of clock represents the highest degree of accuracy obtained by a pendulum clock, and clocks of this kind were the standard timekeepers in many observatories until the introduction of the quartz crystal clock. A large number are still in use for various duties in observatories all over the world.

It seems rather an omission in the exhibition not to have an example of the gravity escapement, for this detached, gravity impulse escapement marked the achievement of the greatest degree of freedom for the pendulum, apart from the Shortt free pendulum clock described above, and it is still the best escapement for tower clocks from which the highest possible standards of timekeeping are required.

The various inventions to compensate a pendulum against variations in temperature

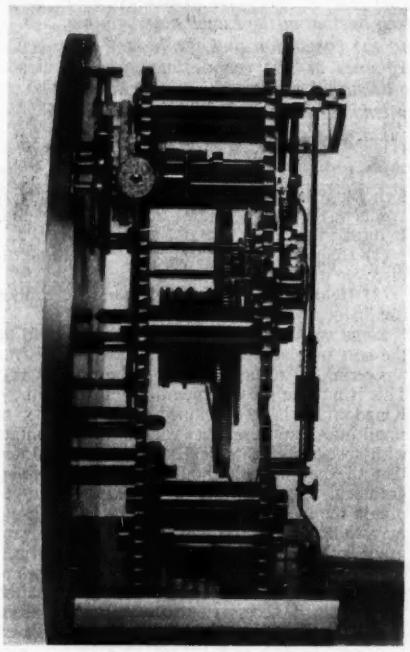

Fig. 6—Side view of Greenwich Dent regulator of 1872

shown include Harrison's "gridiron," in which brass and steel rods act through their differential expansion and so keep the distance between the centres of suspension and oscillation constant. Another method is the Graham mercury compensation, in which the bob consists of a jar filled with mercury. The upward expansion of this compensates for the downward expansion of the pendulum rod.

In the Ellicott method of compensation, also shown, a brass rod fixed to the pendulum depresses levers in the pendulum bob and so raises the bob itself to cancel out the expansion of the steel pendulum rod, and still another kind of compensation in the same group is the widely used zinc-steel assembly of tubes, which again keeps the distance between the suspension and oscillation centres constant. All these devices act by compensating for the expansion and contraction of the pendulum rod, but the final example in the group is an Invar pendulum, the rod of which is made of the special nickel-steel alloy which obviates the need for such "compensations" because it has a negligible temperature coefficient. This alloy, of course, has now largely been adopted for the pendulum rods of precision clocks and has rendered all forms of compensation obsolete.

Barometric variations also contribute a source of error in the time of swing of a pendulum, and the various devices to compensate for these are shown in a group of drawings and photographs, no actual examples being exhibited. The flexible suspension of a pendulum is another important detail of its construction, and the various forms devised during the development of pendulums are illustrated by a very fine set of coloured drawings produced in the Science Museum drawing-office. Cords, bearings and knife edges have all been used at various times, but the familiar flexible flat spring is so superior to other types that it is now the accepted standard.

Nine fine models of the various kinds of escapements used with pendulums form a group of their own and are well worthy of study. Again, the absence of the famous gravity escapement is an unfortunate omission. The rest of the exhibition is made up of photographs of unusual pendulums, including that in Rye Church, Kent, and of portraits of Huyghens and a chronological table of his inventions in connection with the pendulum.

The whole exhibition is well planned and displayed, and tells its story exceedingly well. We have become so used to the pendulum clock as a timekeeper that we are apt to take it completely for granted and to accept the remarkably high standard of time measurement that it affords without comment. This exhibition serves as a reminder of the amount of scientific research and technical skill that have been needed to provide the reliable and useful form of timekeeper upon which we depend so much, and for that reason alone it is a valuable source of information. It is also an assembly of examples of fine craftsmanship which can be appreciated and enjoyed by the ordinary user of clocks as well as by the expert horologist, and the Science Museum and the Antiquarian Horological Society are to be congratulated upon its organisation.

Clean Air Act, 1956

On January 1, those provisions of the Clean Air Act became effective which give local authorities power to establish smoke control areas, in which smoke from buildings will be strictly curtailed, or banned altogether. The Orders establishing these areas will require confirmation by the Minister of Housing and Local Government. The procedure to be followed is explained in a memorandum which has been sent to local authorities by the Ministry. It is contemplated that in the larger towns smoke control will be undertaken in gradual stages over a period of years. The memorandum explains that progress will be governed by the supply of smokeless fuels, by the rate at which fireplaces can be converted, and by the speed with which local authorities are able to formulate and carry through their plans for smoke control. The memorandum states that altogether there will be enough of the various smokeless fuels in the next few years for a substantial start to be made. It stresses the importance of consultation between local authorities and the producers and distributors of fuel, and says that the Government is setting up advisory committees of producers and distributors to help in dealing with problems of smokeless fuel supply. In smoke control areas, grates and other appliances in which smokeless fuels cannot be burnt satisfactorily will have to be altered or replaced. In houses, except those started after July 5, 1956 (the date on which the Act was passed), 70 per cent of the cost of the necessary adaptations, as approved by the local authority, will be borne by the local authority and the Exchequer.

National Lending Library for Science and Technology

By D. J. URQUHART

D.S.I.R. has been charged with the planning of a National Lending Library for Science and Technology. The purpose of this library will be to help users of scientific literature and bibliographical organisations to obtain the literature which is not available locally. The library will take over from the Science Museum Library the responsibility for providing a lending service and it will also take over from that library some of its literature. The new library will be located outside the London area and will aim at providing a postal lending service for all types of organisations. The author of the paper, here abstracted after presentation on January 5 before the University and Research Section of the Library Association, after making several assumptions, comes to the conclusion that the library may have to hold 12,000,000 to 18,000,000 volumes in 100 years' time, that the site plan should provide for this material to be stored and issued in the traditional form, and that the volume of inter-library lending and the demand on the new library is likely to increase more rapidly than the volume of world literature.

THE Ninth Report of the Advisory Council on Scientific Policy[1] states :

"We are informed that a decision has been taken to place ultimate responsibility for the National Science Lending Library on the Department of Scientific and Industrial Research and that the Department has been given authority to start planning such a library. Now that the D.S.I.R. has been specifically charged with this task, we hope that another year will not pass without some concrete evidence that our recommendations are being put into effect."

Within D.S.I.R. it has been decided that the new library shall be called the National Lending Library for Science and Technology. The purpose of this paper is to let you know what some of us in D.S.I.R. are thinking about the creation of this library, and to invite your observations and suggestions, now, whilst our ideas are still fluid.

Since 1915 research activities throughout the world have increased the volume of recorded scientific and technical information considerably, and an important problem now is to ensure that this information reaches those who can use it. Shorn of its complexities, the solution to this problem requires :

(1) That users must know what exists.

(2) That users must be able to obtain what they wish to read.

It is the job of guides to scientific literature to provide the user with some means of finding out what exists. Already even these guides occupy an appreciable space, and they will grow in volume and complexity as scientific literature expands. Unless users know how to use those guides and have easy access to them they cannot discover what literature they want.

In considering what "easy access" means we have to remember that whilst scholars have been content for over 2000 years to travel to great libraries, the user of science is seldom prepared to go far for his literature. He works in the laboratory, the factory, the hospital, the farm or the mine. He needs scientific literature where he works or lives. He is hard-pressed for time. He may be creating a world in which the problem of how to spend leisure time is affecting more and more people, but that is not his problem. His time is fully and over-fully occupied. A recent survey (as yet unpublished) has shown that the users of science in industry do the greater part of their technical reading at home. Such is the pressure on these creators of the future. They are, and are likely to remain, in short supply. The community benefits enormously from their activities. They can only make their maximum contribution if they have the services they need, and these services are as convenient as possible.

This means that the potential user of science must not only be able to discover what literature he needs, he must also be able to obtain it easily. Elsewhere[2] I have suggested how improved local technical library services might be created. When local facilities fail we should still seek to bring the literature to the user.

A national lending library for science and technology appears to come into this chain of events at the very beginning and at the very end. It must :

(1) Help the bibliographical organisations to discover what exists.

(2) Help the user to obtain what he cannot obtain locally.

Some consider that the new library should be the sort of place which would have devices for answering all technical questions automatically. This is not the present intention. In the United Kingdom we have developed a large number of small information services each in direct contact with specialists in its field. It is only proposed that the new library should assist these bibliographical organisations by helping them to obtain the literature they need. The new library may well become the natural place to fill gaps in the coverage of the existing abstracting services. Perhaps the future development of new types of equipment for storing and retrieving information may make it necessary to create a centralised information service in the library. However, at present we only seek to create a lending library which will assist the existing information services and the users of scientific literature.

Science Museum Library

The D.S.I.R. might very well have had to assume responsibility for such a library much earlier in its history. This was unnecessary as Dr. Bradford, sensing the changing attitude towards scientific research which followed the end of the first world war, on his own initiative began to develop the Science Museum Library as a national lending library for science and technology. In 1912 that library received some 570 current serial publications. By 1925 a considerable expansion had begun with the object of providing in one place a complete collection of the scientific and technical periodical literature of the world. In that year alone some 1400 current serials were taken for the first time by the library,[3] and by the end of 1936 it was estimated that the library contained some 9000 current serials.[4]

The second world war, whilst it focused attention on the importance of the Science Museum Library's collection of literature, greatly slowed up its development. In the post-war years economic, and other difficulties, and, more recently, the site limitations in that part of South Kensington which will hold the expanded Imperial College of Science and Technology, have restricted the development of that great library. Briefly, it is proposed to overcome this difficulty by creating outside the London area a new lending library for science and technology. When this has been done the Science Museum Library will cease to be responsible for providing a national lending service and will concentrate on meeting the needs of the Science Museum and the growing Imperial College.

Starting the New Library

You may wonder how it is proposed to transfer the function of providing a national lending service from an existing library to one which at present only exists in the imagination. As with all the problems the creation of the new library raises, no specific solution has yet been decided upon. The tentative solution envisages that during the next few years the collections earmarked for the new library should be built up. It is not, however, envisaged that the earmarked literature should be placed in cold storage. The real purpose of the new library is to improve the lending service in the country, and in consequence it is proposed that the earmarked literature should be placed where it can be used. In particular, it is hoped that it will be possible to place most of it at the disposal of the Science Museum Library and its lending and photographic services. To facilitate this we are at present trying to obtain some temporary storage space near the Science Museum Library.

The problem of what to earmark for the new library is complicated by the fact that it is visualised that some part of the existing collections of the Science Museum Library will eventually be transferred to the new library. What this part will consist of we do not yet know. It is clear that it will consist mainly of material for which the Science Museum and Imperial College have no appreciable demand. It may also include some literature which will become available due to the reorganisation of the Departmental libraries of the Imperial College.

We think that we should seek rather to make sure there are no gaps in the collections of currently issued literature than to fill up gaps which have already occurred. In view of this it is contemplated that we should seek to make the new library comprehensive from some recent date such as 1950, and actively seek to obtain only the more important earlier material, but to accept a wider range of literature.

Once the earmarked collections have been built up it should be possible to transfer the function of providing a lending service to the new library without causing considerable chaos amongst potential users if (*a*) the transferred functions relate to a definable section of the literature, (*b*) the external forms and procedures used by the Science Museum Library are accepted in the initial phases by the new library, and (*c*) the literature retained by the Science Museum Library which is not duplicated by the new library should continue to be available for loan. Whether the transfer of function will be one large operation or whether it will be a series of operations has not yet been decided, but it is probable we shall gather some experience of this problem by a special attempt we are making to improve the collection of Russian scientific literature.

Decentralisation

So far in this paper I have talked of a library which carries out its functions by physically collecting the material with which it is concerned. Before this idea crystallises further let us review the whole concept. The fundamental responsibility of the new library is to organise and promote a lending service for the literature of science and technology. It could do this by collecting material. It could also do it by promoting other collections, and the problem arises as to what policy should be pursued in particular about promoting collections under the control of other organisations. The new library, for instance, might delegate responsibility for maintaining comprehensive loan collections in particular fields or of particular types of literature to other organisations specialising in those fields. If this were done it would be essential that the delegation of responsibility should relate to some clearly definable type of literature. Such delegation might be defined by subject, country or origin, language or nature of issuing organisations. This is a subject we propose to study further and on which we would welcome suggestions.

Initially, it was suggested that the new library might protect itself from excessive demands for the more frequently used material by supporting a number of regional libraries. At first sight, such a policy appears to have many attractions, but some consideration of the mathematics of probability indicates all too clearly that centralisation, other things being equal, would provide a

much better service. For instance, if the postal service is used, it appears that as a rule two or three copies of a publication in one lending library would provide a better service than could be obtained from one copy in each of ten regional lending libraries. This does not imply that local services are unnecessary. Indeed, as I have suggested earlier, they have the special function of helping the potential user of science to discover what he wants to read.

Initial Volume of Accessions

Although the new lending library will be administered by D.S.I.R. it is not intended that the collections of the new library should be limited to those fields of pure and applied science in which D.S.I.R. has an interest. Indeed, it is proposed that the new library should provide a service in the whole field of pure and applied science, but that in some fields, particularly medicine, the collections should be limited in extent. How far the new library will become concerned with that part of the social science field which has become the joint responsibility of the Medical Research Council and D.S.I.R. is not at present clear. It is intended that the new library will cater not only for those carrying out scientific research, but also for those who are concerned with applying the results of research.

To plan this new library it is necessary to have some idea as to the volume of literature the library will receive when it begins to work normally. This is a question on which we would like your assistance. In considering this it is important to remember that the function of the library will be not so much to evaluate the literature as to collect it so that others may evaluate it. It is not easy to specify exactly what standards should be applied. Bradford, I believe, worked on the principle that if literature existed it was good enough for the Science Museum Library. If you worked on a higher standard how could you define the standard without eliminating some of the literature which might be useful ? In 1955, the Science Museum Library was collecting some 9000 current periodicals—about the same number as it apparently was collecting in 1938. The 1955 figure is undoubtedly more realistic than the 1938 one was, but nevertheless it does suggest that the Science Museum Library, in common with other libraries, has not been keeping pace with the growth of scientific literature within the last two decades.

Perhaps we can do little more than say that if 10,000 volumes is the present annual input into the Science Museum Library the annual input required to have a comprehensive collection should be about twice this figure. Support for this view is given by the fact that in 1955 the rate of acquisition to the Science Museum Library would only be doubling its volume in every thirty years or so. This is a much slower rate of growth than has been reported by other large libraries. For instance, F. Rider[3] has reported that ten of the larger university libraries in the U.S.A. have been doubling in size every sixteen years for some considerable time.

Future Accessions

If a library is doubling itself every twenty years, after a century the volume of material in the library (and the input rate) would be thirty-two times as great. Such a rate of expansion of world scientific activity is not at present impossible. All nations are determined to increase their output of scientists. In this country the present output of scientists and engineers is double what it was in 1938, and the Advisory Council on Scientific Policy has recommended that the universities should seek to double their present output again by 1965 to 1970.[6] This sort of thing cannot, of course, go on indefinitely or otherwise in a century or so everyone would become a graduate in science or engineering. What the limits are I do not know, for we seem to know more about our coal resources than our intellectual resources. Nevertheless, there are signs that the limits of our intellectual resources are in sight.

Let us assume for the moment (*a*) that the creative intellectual resources of the most advanced quarter of the world could be doubled or trebled, (*b*) that three-quarters of mankind has barely begun to develop its intellectual resources, (*c*) that the world population will increase between 50 and 100 per cent in the next century, (*d*) that all races have equal intellectual capacity, (*e*) that each race will have fully developed its intellectual resources within the next century. We would then expect to find that the world's output of scientific and technical literature would be twelve to twenty-four times the existing output. Perhaps some serious attempt will be made to rationalise the existing arrangements. Perhaps in a century we shall all write, if not speak, one language. Perhaps . . . but " the future's not ours to see." We can only hope for the best and plan for the worst. In a century we might expect, if not a thirty-two-fold increase, in the annual output of scientific and technical literature, a twelve-fold or twenty-four-fold increase. Unless mankind tackles the linguistic babel most of this will not be in the English language. In all we might expect the next century to produce 12,000,000 to 18,000,000 useful volumes in science and technology. The annual output of literature in 100 years' time would be approximately equal to the total volume of literature in the Science Museum Library at present, and possibly one-quarter of it will be in Chinese. There are two consolations to be derived from this analysis. The annual output of literature would then be approximately constant, and Chinese is apparently more like English in structure than any other language. It has no grammar and no inflections so mechanical translation into English should be relatively simple.

Before we leave these calculations let us note one thing in the picture our assumptions lead to —the growth of scientific activity in the world as a whole in the next century will be appreciably greater than the growth of scientific activity in this island. However we try to repaint our picture of the future, making other guesses, we get the same sort of result. Personally, I think this result means one thing—we must seek to make the maximum use of the world's scientific output. We must not only collect the literature. We must see that it is used.

Location

Fortunately, the location of the new library has not yet been selected, so it is still possible to find a site which will permit of considerable expansion. As the library is to be a lending library which will operate primarily through the postal services, the first consideration is to find a place which has fairly rapid postal communication with all parts of the Kingdom. This applies to a number of towns in the northern half of England. So besides taking into account the postal considerations it will be possible to consider other factors such as the proximity of large organisations which would benefit from the existence nearby of a large scientific library. Your suggestions on this point would be particularly welcomed. In considering them it should be remembered that serial publications will form the main part of the collections of the new library. For serials it is possible to predict roughly the demand for future issues from the demand for existing issues, and thus it is possible to order the right number of copies to maintain any level of loan service. Inevitably a policy of duplicating to improve the lending service would also improve the reference service.

Automation

Although initially the new library may have to provide literature in its traditional form that does not mean that internally the library should look like a traditional library. The problem which faces us is how far the latest techniques, or even those which are in the process of development, could be usefully used ultimately in the new library. The answer to this problem will condition the shape of the buildings and the internal recording procedure which should be adopted. For instance, the question arises whether computer type storage equipment could be used for all, or the major part, of the records of the new library. The operations which might be covered by such equipment are those which are now variously covered by such things as catalogues, accession registers, store records, lending records, binding records, listing for hand lists or demands on publishers. One way in which such equipment might function, particularly as regards serial publications, can now be discerned. The machine would have to be told in its own peculiar language all the movements of the publications it was controlling. It would have to know when new parts arrived, which stores they were sent to, when they were sent on loan and to whom, when they were returned, and when title pages and indexes were available. The machine, if it was to be useful, should then be able to handle the daily load of requests for publications, dividing them up and sending them to the appropriate stores for action. Such a machine should then be able to prepare recall postcards for overdue loans, indicate when requests were received for material already on loan, and probably when parts of serials which should have arrived from publishers have failed to arrive. It should not be difficult for a machine which can do these things to be able to prepare a list of material which is complete on shelves awaiting binding, and, indeed, if the policy of the library was only to bind material for which the demand was low the machine ought to be able to take that into account in preparing a list of what ought to be bound. In addition, such a machine should be able to provide valuable control statistics relating to the type of literature in demand and for which serials additional copies are required to provide a good standard of service.

The Future

Despite all our efforts to discern the shape of things to come, I have no doubt that whatever plans are prepared now for this library all the guesses will not be right. That cannot be helped. The future is an uncharted sea. What is important is that the new library should have at its helm men capable of taking advantage of future possibilities as soon as they arise. At a first glance you may think this an easy matter : that a first-rate scientific library should attract first-rate scientists and almost inevitably this library would be kept in the vanguard of progress. But unfortunately that will not happen automatically. In other disciplines men with first-class intellects have been attracted to library posts because after all the library is their workshop. But this does not pertain in science. The scientist has at his disposal laboratories which seem more exciting than book stores and apparatus more intriguing than bookshelves. As a rule, he is content to leave what from the outside is to him a routine activity—the collection and making available of literature—to lesser minds than his. He desires to continue to create and add to the mountains of human knowledge and avoid routine work. Can we blame him ? That is what the problem looks like from the outside, however complex the problem may be from the inside.

Somehow we must seek to change this. We must give good scientists a glimpse of the library problem from the inside. Perhaps this could be done by creating " readerships " and by having laboratories in the new library. The laboratories could usefully be concerned with developing suitable techniques for handling the growing volume of information. In addition, scientists are necessary to study the flow of information. By such means we may spread the realisation that whilst science has created a technique for extending without visible limits man's knowledge of nature, it has not yet produced satisfactory techniques for making sure this knowledge is used. Then it will be more widely appreciated that organising knowledge is a creative task which is second to none. Let us not forget that unless something is done the application and progress of science may be restricted by our inability to handle the growing volume of existing knowledge. To make sure that this does not happen appears to me to be an essential task of a research wing of the new library.

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Naval Construction in 1956

No. III—(*Concluded from page 67, January 11*)

Russia

SIX large cruisers of the improved "Sverdlov" class were under construction during the year.

Several of a class of eight very large fleet destroyers (Fig. 8) were completed. Known as the "Tallinn" class, they are flush-decked with a displacement of 3500 tons, an overall length of 440ft, a beam of 44ft and a draught of 15½ft. Their armament comprises four 3·9in guns in two twin turrets, one forward and one aft, twelve 37mm anti-aircraft guns, ten 21in torpedo tubes in two quintuple banks amidships between the two wide apart and low, raked funnels, and two anti-submarine rocket launchers. A two-shaft arrangement of geared turbines aggregating 100,000 s.h.p. gives a speed of 38 knots.

More of the twenty-four flush-decked destroyer escorts of the "Kola" class were also completed. These have a displacement of 1100 tons standard and 1500 tons full load, with an overall length of 305ft, a beam of 33ft and a draught of 11ft. They are armed with four single 3·9in guns conventionally disposed in single mountings, two forward and two aft, two 37mm A.A. guns, three 21in torpedo tubes, and anti-submarine depth charges and racks. Their main machinery is of 30,000 s.h.p., equal to a speed of 30 knots.

Of more recent design are the twelve frigates of the "Riga" class (Fig. 9), with a displacement of 900 tons standard and 1200 tons full load, a length of 279ft, a beam of 29½ft and a draught of 10ft, an armament of three 3·9in guns in single mounts, two forward and one aft, four 30mm A.A. guns and three tubes, and geared turbines giving a speed of 25 knots. This type seems to be divided into two groups, the later having a more sturdy and more multiple-strutted lattice mast for the support of more complicated radar aerials.

Some seventy-eight submarines were completed or near completion by the end of the year.

France

The design and armament of the two new aircraft carriers, the "Clemenceau," being built at Brest Dockyard and the "Foch," at Penhoët-Loire, has been modified. With a displacement of 22,000 tons standard and 27,307 tons full load, an overall length of 845ft, an extreme width of 151ft and a draught of 25ft, they will now be armed with twelve 3·9in guns and some 30mm A.A. weapons. They will have an angled deck 543ft long and 96½ft wide at 8 deg. off the centre line, two steam catapults and two lifts, and will carry sixty aircraft. The propelling plant consists of six boilers and geared turbines of 126,000 s.h.p., turning two screws at a speed of 32 knots.

The new anti-aircraft cruiser "Colbert" was launched (floated out of dry dock) in Brest Dockyard on March 24, 1956. She will displace 8270 tons standard and 11,000 tons full load, with an overall length of 597ft, a beam of 63½ft and a draught of 19ft. Twin screw propelling machinery of 86,000 s.h.p. will give her a speed of 32 knots. Her armament will include sixteen 5in dual-purpose guns in twin turrets and twenty-four 2·25in anti-aircraft guns in twin mounts. She will have a platform for a helicopter, and provision has been made in the design for the fitting of guided missiles.

A prototype fast anti-submarine escort, to be named "La Galissonniere," is being built at Lorient Dockyard. All five of the new radar picket destroyers of the "R 53" type were completed or nearing completion at the end of the year. Eleven new destroyer escorts of the "E 52" type were in various stages of construction or completion. The "Narval" (Fig. 10), first of a class of six ocean-going submarines to be built, has a displacement of 1430 tons surface and 1800 tons submerged with a length of 256ft, a beam of 23¾ft, and an armament of eight torpedo tubes. Diesels of 4000 b.h.p. give a surface speed of 16 knots and electric motors of 5000 h.p. a submerged speed of 18 knots. Other new construction includes ten smaller submarines, twelve patrol vessels,

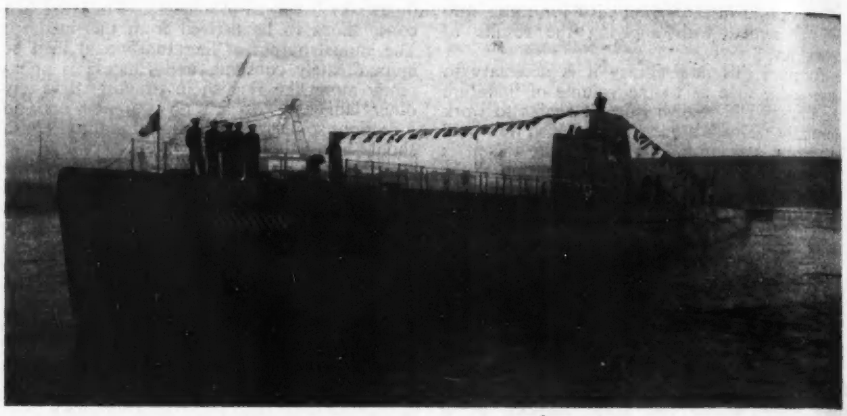


Fig. 10—"Narval," new French ocean-going submarine

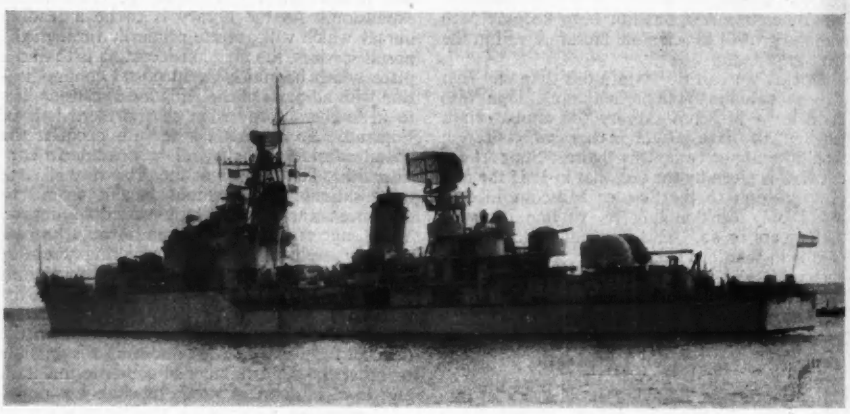


Fig. 11—"Friesland," completed March 22, 1956. New Netherlands destroyer

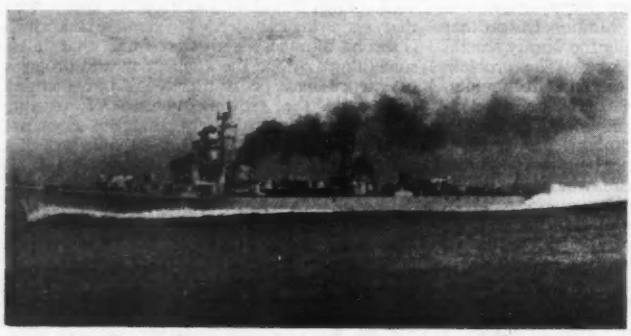


Fig. 8—"Tallinn" class. New Russian giant destroyer

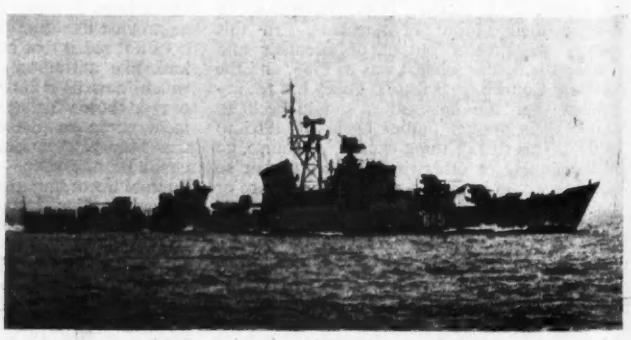


Fig. 9—Later "Riga" class new Russian frigate

Fig. 12—"Aragua," completed February 14, 1956. New Venezuelan destroyer

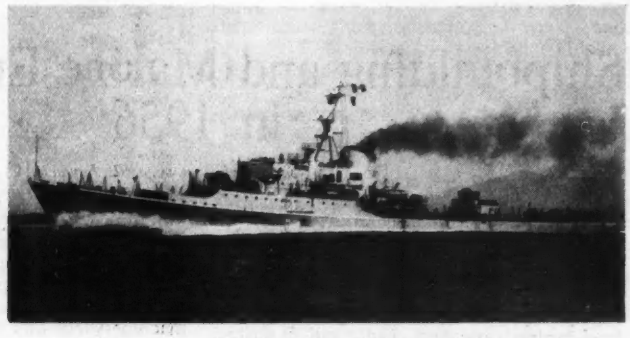


Fig. 13—"Juan Jose Flores," completed 1956. New Venezuelan light destroyer

and sixteen coastal minesweepers. The transport "Ile D'Oleron" is being converted into an experimental guided missiles ship.

Netherlands

Of eight new escort destroyers the first, the "Friesland" (Fig. 11) was completed on March 22, 1956, and the "Groningen" and "Limburg," the name ship of the class, were scheduled to be completed at the end of the year. Displacing 2476 tons standard and 3070 tons full load, with an overall length of 380½ft and a beam of 38½ft, they are armed with four 4·7in guns, six 40mm A.A. guns, and two four-barrelled anti-submarine rocket throwers or depth charge mortars, but they have no torpedo tubes like orthodox destroyers. They are also unusual in having side armour and deck protection, like light cruisers. The main machinery comprises a two-shaft arrangement of geared turbines of 60,000 s.h.p., giving a speed of 36 knots.

Japan

The "Harukaze" (Fig. 14), completed by the Mitsubishi Zosen Company, Nagasaki, on April 26, 1956, and the "Yukikaze," delivered by Shin-Mitsubishi Jyuko Company, Kobe, in August, are the largest and the first destroyer-hulled vessels built in Japan since the second world war. Of mixed Japanese and American influence in design and appearance, they have a displacement of 1700 tons with a waterline length of 347½ft and a beam of 43½ft. The armament comprises three 5in guns, eight 40mm A.A. guns, two hedgehogs, eight K-guns, two depth charge racks and throwers. Two Hitachi-Babcock boilers and two sets of Mitsubishi-Escher Wyss geared turbines of 30,000 s.h.p. give a speed of 30 knots.

Fig. 14—"Harukaze," completed April 26, 1956. New Japanese destroyer

Fig. 15—"Akebono," completed March 20, 1956. New Japanese destroyer escort

The destroyer escort "Akebono" (Fig. 15), completed by Ishikawajima Jyuko Company, Tokio, on March 20, 1956, has a displacement of 1075 tons standard and 1350 tons full load, with an overall length of 301ft and a beam of 28½ft, two 3in guns, four 40mm A.A. guns and eight depth charge throwers. Two Ishikawajima-Foster Wheeler boilers and two geared turbines of 18,000 s.h.p. give 28 knots. Her half-sisters "Ikazuchi" completed by Kawasaki Jyuko Company, Kobe, and "Inazuma," completed by Mitsui Zosen Company, Tamano, differ in that they have only one funnel instead of two and have diesels of 12,000 b.h.p., equal to 25 knots.

Venezuela

The destroyer "Aragua" (Fig. 12) third of the class, was completed by Vickers-Armstrongs, Barrow-in-Furness, on February 14, 1956. Displacing 2600 tons standard and 3300 tons full load with a length of 402ft and a beam of 43ft, she carries six 4·5in guns, sixteen 40mm A.A. guns and three 21in torpedo tubes at a speed of 34·5 knots, obtained from two boilers and Parsons geared turbines of 50,000 s.h.p. Three light destroyers of 1150 tons, the "Almirante Clemente," "José Moran" and "Juan José Flores" (Fig. 13), were completed by Ansaldo, Leghorn.

Code of Practice

CENTRAL HEATING BY LOW-PRESSURE HOT WATER

Code 341.300-307: 1956. Price 15s.—This code deals with the work involved in the general planning, designing and installation of a system of central heating by low-pressure hot water (i.e. where the system is open to the atmosphere at one or more points) and utilising appliances such as column radiators, convectors, surface panels, unit heaters and pipe coils. Its recommendations are applicable to central heating installations suitable for the whole range of buildings, viz. private residences, multi-storey flats and office buildings, schools and general industrial premises. The recommendations assume that the design of such installations will be entrusted to qualified engineers and that the execution of the work will be carried out under expert supervision. The head-code deals with the general aspects of central heating by low-pressure hot water. Seven sub-codes cover in detail the subjects indicated by their titles. Each sub-code includes a list of the British Standards relevant to its subject. The titles of sub-codes are: boilers and calorifiers; storage vessels; pipework, fittings, valves, taps and cocks; appliances (column radiators, surface panel, convectors); unit heaters; power-driven circulating pumps for low-pressure hot water heating installations; and thermal insulation. The committee, while basing its design recommendations on present accepted practice, has drawn attention to the work undertaken by a committee appointed by the Minister of Works to inquire into the need for adjustment of the basic outside design temperature for heating installations. The findings of this committee will be published by H.M.S.O. as Post War Building Study No. 33. The committee has also maintained close liaison with the Institution of Heating and Ventilating Engineers and has used in the code information and tabulated data published in the Institution *Guide to Current Practice*.

Shipbuilding and Marine Engineering in 1956

No. III—(*Concluded from page 62, January 11*)

Liners

LAST year saw the entry into service of a number of liners including the Canadian Pacific "Empress of Britain" built and engined by the Fairfield Shipbuilding and Engineering Company, Ltd., and described in our issues of May 11 and 18, 1956; the "Reina del Mar" a description of which appeared in our issue of June 22, 1956, delivered by Harland and Wolff, Ltd., to the Pacific Steam Navigation Company; the "Carinthia," described in our issue of August 10, 1956, built and engined for the Cunard Steam Ship Company, Ltd., by John Brown and Co. (Clydebank), Ltd. All these ships were illustrated on Plate 9 of our issue of January 4, 1957. The "Bergensfjord," constructed by Swan, Hunter and Wigham Richardson, Ltd., and engined by Stork Brothers, Hengelo, Holland, for the Norwegian-American Line, and the troopship "Nevasa," completed by Barclay Curle and Co., Ltd., for the British India Steam Navigation Company, Ltd., and described in THE ENGINEER of August 3, were illustrated in our issue of January 4.

Cargo-Passenger and Cargo Ships

For the South American service of Norwegian owners, Alexander Stephen and Sons, Ltd., built and engined the M.V. "Crux"; the ship carries a deadweight of 6530 tons on a load draught of 23ft and a length, breadth and depth of 400ft, 57ft and 25ft, respectively. Twelve passengers are accommodated in single and two-berth rooms and there are five cargo holds served by one 50-ton, one 30-ton and a complement of 3-ton, 5-ton and 10-ton derricks. Three 180kW diesel-driven generators meet electrical requirements and a loaded service speed of 14½ knots is maintained by a four-cylinder Stephen-Doxford diaphragm oil engine.

At Belfast, Harland and Wolff, Ltd., completed the M.V. "Eden" for the Royal Mail Lines, Ltd., and the following are the main particulars: length between perpendiculars, 415ft; breadth moulded 58ft 6in; depth moulded to shelter deck 38ft 4in, and a gross tonnage of 7790. Accommodation is provided for twelve passengers. For handling the cargo carried in the four main holds there are one 30-ton, four 10-ton and eight 5-ton derricks powered by electric winches. Electrical energy is provided by three 156kW diesel-driven generators and the propelling machinery consists of a Harland and Wolff two-stroke, single-acting, opposed piston diesel engine having six cylinders of 620mm bore by 1870mm combined stroke. For the same owners the company built, at its Govan yard, the M.V. "Tuscany," which has the same dimensions as the "Eden" but does not carry passengers.

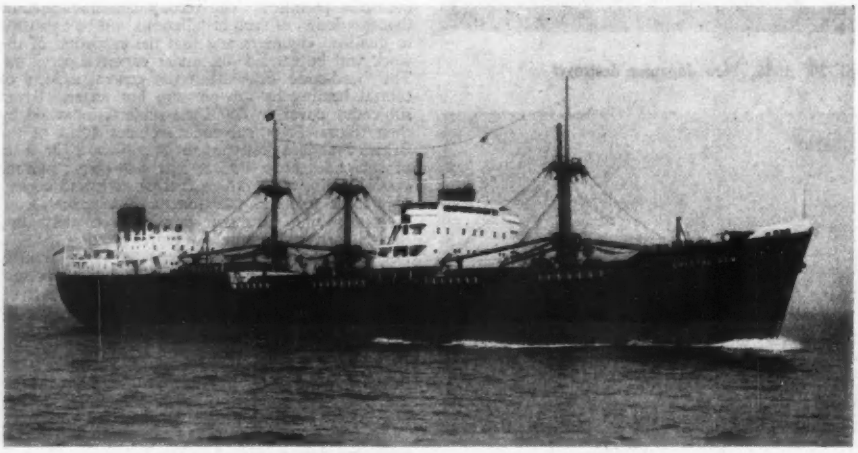
Henry Robb, Ltd., completed several ships for the Union Steam Ship Company of New Zealand, Ltd. They included the "Kumallo," which has a length between perpendiculars of 235ft by 45ft breadth moulded by 15ft 3in depth moulded to upper deck, and a deadweight capacity of 1645 tons on a mean draught of 13ft 3in. There are two large holds, electric deck machinery and the ship is propelled by an eight-cylinder British Polar two-stroke diesel engine, developing 1280 b.h.p. at 250 r.p.m. The "Kaimai" carries a deadweight of 2100 tons on a mean draught of 16ft and a length between perpendiculars of 250ft by 41ft 6in beam by 17ft 9in depth moulded to upper deck. Cargo is carried in three holds equipped with a total of eight 5-ton derricks operated by electric winches. Three 114kW diesel-driven generators provide electrical power and the propelling machinery consists of a Clark-Sulzer mark T.P.D.48 two-stroke diesel engine of 1500 b.h.p. at 225 r.p.m. A third ship completed for the same owners was the twin screw "Kaitoa," which has a length between perpendiculars of 290ft by 43ft beam by 19ft 6in depth moulded to upper deck, and is designed for a deadweight of 3030 tons on 17ft 3in mean draught at 11 knots. Two six-cylinder "Polar" diesel engines are installed for propulsion purposes.

Ellerman and Bucknall Lines, Ltd., took delivery of the 5348-ton deadweight cargo liner "Almerian" from The Caledon Shipbuilding and Engineering Company, Ltd. The ship, which has a length overall of 377ft, a breadth moulded of 53ft, and a depth to shelter deck of 32ft 9in, has a speed of 13¼ knots and carries the cargo in five holds fitted with MacGregor steel hatch covers. There are thirteen derricks, including one to lift 35 tons, operated by steam winches. One 35kW and two 25kW steam-driven generators are provided and the ship is propelled by a triple expansion steam engine and a Bauer-Wach exhaust turbine, developing 3500 i.h.p. at 92 r.p.m., supplied by the Central Marine Engine Works, and taking steam from three oil-fired boilers constructed by the shipbuilders.

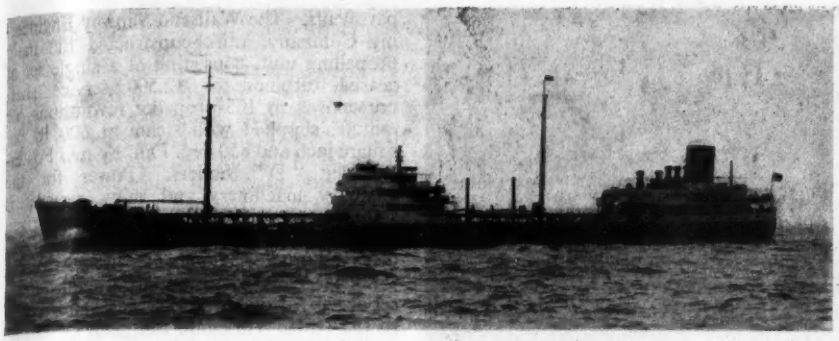
Closed shelter deck cargo liner "Michael C"

The bulk sugar carrier "Crystal Gem," illustrated on this page, was built by Hawthorn, Leslie (Shipbuilders), Ltd., for the Sugar Line, Ltd., and has a deadweight capacity of 9750 tons at a service speed of 12 knots. There are five holds, with wing cargo spaces, suitable for bulk cargoes such as sugar, grain or iron ore, and arranged for loading and discharging by grabs. Each hatch is fitted with MacGregor steel covers and served by two 10-ton derricks, with the addition of a 25-ton derrick at No. 2 hold, operated by steam winches. Two 75kW diesel-driven generators and one 20kW steam-driven generator supply the necessary electrical power. The ship has the following dimensions:—Length between perpendiculars, 430ft; breadth moulded, 61ft; depth moulded to upper deck, 37ft 3in, and draught, 24ft 6in, and is powered by a Hawthorn-Doxford diaphragm oil engine having four cylinders of 600mm bore by 2320mm combined stroke, and developing 3300 b.h.p. at 108 r.p.m. A sister ship, the M.V. "Crystal Jewel," was completed for the same owners at the South Bank yard of Smith's Dock Company, Ltd.

For the Palm Line, Ltd., Swan, Hunter and Wigham Richardson, Ltd., completed at its Neptune Works the "Bamenda



Bulk sugar carrier "Crystal Gem" of 10,000 tons deadweight



18,000 tons deadweight tanker "Horomya" for Shell Tankers, Ltd.

Palm" and "Badagry Palm," the ships having a length between perpendiculars of 415ft by 58ft beam by 35ft depth moulded to shelter deck. There are five cargo holds and a deep tank and a complement of 5-ton and 10-ton derricks, including one to lift 75 tons, powered by electric winches. A 100-ton capacity reciprocating pump handles the palm oil carried in the deep tank. All the auxiliary machinery is electrically driven and the power is supplied by three 250kW diesel-driven generators. A four-cylinder Swan, Hunter-Doxford oil engine designed to develop 4500 b.h.p. at 118 r.p.m. gave the ships a trial speed in excess of 15 knots. The same builders also delivered to Panamanian owners the closed shelter deck cargo liner "Michael C," illustrated on page 94, which has a length and breadth of 435ft and 60ft respectively, and a depth moulded to shelter deck of 39ft. Serving the five cargo holds are one 30-ton, four 5-ton and six 10-ton derricks, and a number of steam winches. Two multitubular boilers provide steam for the auxiliary machinery, and the propelling machinery consists of a Swan, Hunter-Doxford oil engine, arranged to burn boiler oil, having four cylinders of 670mm bore by 2320mm combined stroke, and developing 4400 b.h.p. at 115 r.p.m.

Also completed for Panamanian owners was the "Michael G. Livanos," built by the Burntisland Shipbuilding Company, Ltd., and propelled by a Kincaid-B. and W. two-stroke, single-acting diesel engine having seven cylinders of 620mm by 1870mm combined stroke and delivering 5500 b.h.p. at 120 r.p.m. The ship, of 11,850 tons deadweight, has a length between perpendiculars of 435ft by 59ft 9½in beam by 39ft 6in depth to upper deck, and five holds served by ten 10-ton derricks, and one 30-ton derrick, operated by electric winches. Power and lighting requirements are met by three 150kW diesel-driven generators. A sister ship, the M.V. "Atalanti M. Livanos," was also completed by the same builders. Other cargo-passenger and cargo ships completed during the year were illustrated on Plate 10 in our issue of January 4.

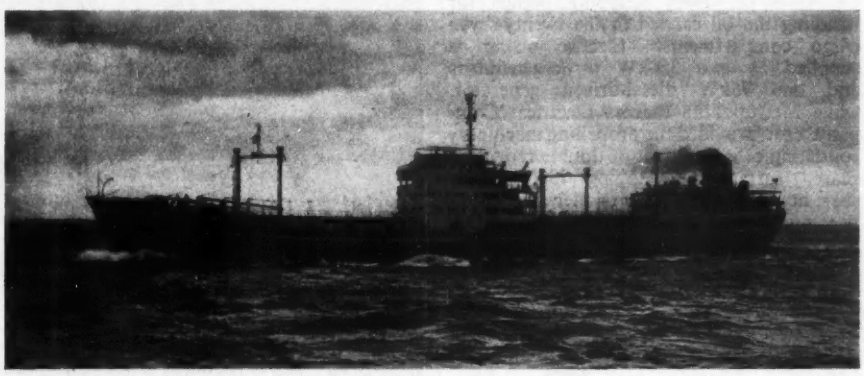
Oil Tankers

Among the small tankers completed was the "Esso Preston," built by Hall, Russell and Co., Ltd., for the Esso Petroleum Company, Ltd., and designed for the carriage of hot bitumen. The ship has a length of 280ft by 42ft beam by 20ft 9in depth, and carries a deadweight of 2300 tons, the bitumen being in five heated centre-line tanks, while water ballast is carried in the wing compartments.

Two electrically operated displacement pumps discharge the hot bitumen at 125 tons per hour, and electricity for the ship's service is provided by two 130kW, 440V, 60 c/s turbine-driven alternators. Propulsion is by a triple-expansion reciprocating engine, of 1300 i.h.p., taking steam at 225 lb per square inch and 500 deg. Fah. from two single-ended oil-fired Scotch boilers.

Shell Tankers, Ltd., took delivery of a number of ships during the year, including the "Horomya," constructed by Hawthorn, Leslie (Shipbuilders), Ltd., and illustrated herewith. The main particulars are: length overall, 557ft; breadth moulded, 69ft 3in; depth moulded, 39ft; deadweight, 18,000 tons, and there are thirty-three cargo oil compartments and one main pump room. For handling the oil cargo there are four Hayward Tyler vertical centrifugal turbine-driven pumps. The electric generating plant consists of two 550kW, 450V, 60 c/s, geared turbine, and one 200kW diesel-driven alternator, and the propelling machinery, constructed by Hawthorn, Leslie (Engineers), Ltd., is a double-reduction, geared turbine installation of 8250 maximum s.h.p. Steam at 500 lb per square inch and 800 deg. Fah. is supplied by two Foster Wheeler "D" boilers. A sister ship, the "Harvella," was built and engined at Belfast by Harland and Wolff, Ltd.

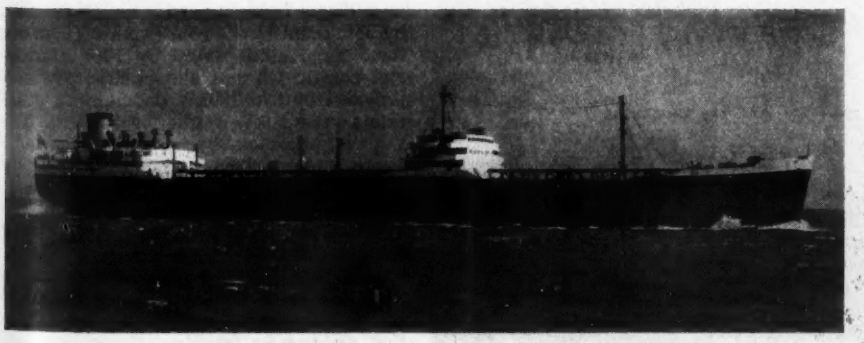
We also illustrate one of the larger units which joined the Shell tanker fleet, the 32,000-ton deadweight S.S. "Vola," built by Hawthorn, Leslie (Shipbuilders), Ltd. The ship has a length between perpendiculars of 635ft by 84ft 3in breadth moulded by 46ft 3in depth moulded and carries the cargo oil in thirty compartments. There is one main cargo pump room equipped with four vertical centrifugal turbine-driven pumps, and three vertical duplex steam-driven stripping pumps. The electrical generating plant consists of two 550kW, 450V, 60 c/s geared turbine-driven alternators and one 150kW diesel-driven alternator. Hawthorn, Leslie (Engineers), Ltd., constructed the single screw geared turbine propelling machinery, consisting of one h.p. and one l.p. turbine and developing a maximum of 14,500 s.h.p., steam being supplied at 600 lb per square inch and 850 deg. Fah. by Babcock and Wilcox integral furnace water-tube boilers. Swan, Hunter and Wigham Richardson, Ltd., built a sister ship, the S.S. "Volvula," at its Wallsend yard, with machinery supplied by The Wallsend Slipway and Engineering Company, Ltd.



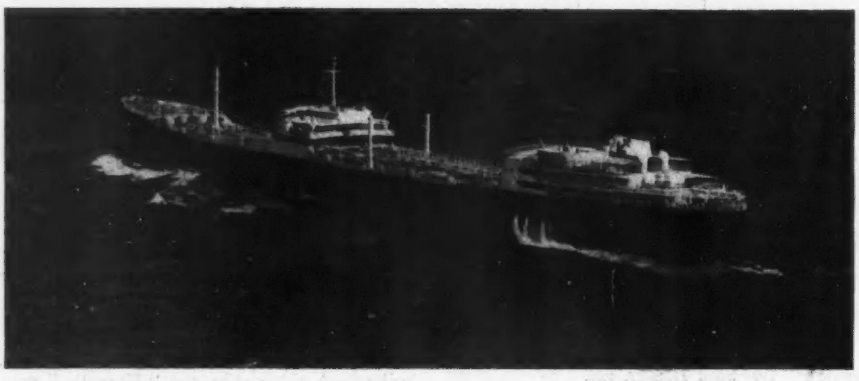
Oil tanker "Vivien Louise," of 24,850 tons deadweight, for British Oil Shipping, Ltd.

A 22,500-ton deadweight tanker, the "Atlantic Knight," was built by the Blythswood Shipbuilding Company, Ltd., to the order of the Ocean Tanker Line, Ltd. There are nine centre and eighteen wing cargo oil tanks and one main cargo pump room containing three 680 tons per hour turbine-driven horizontal centrifugal cargo pumps and two 180 tons per hour stripping pumps. David Rowan and Co., Ltd., constructed the propelling machinery, consisting of a single set of double reduction geared turbines developing 8000 s.h.p. at 105 propeller revolutions per minute and taking steam at 450 lb per square inch and 780 deg. Fah. from two Babcock and Wilcox boilers.

Among the oil tankers completed by the



Oil tanker "Vola" of about 32,000 tons deadweight for Shell Tankers, Ltd.

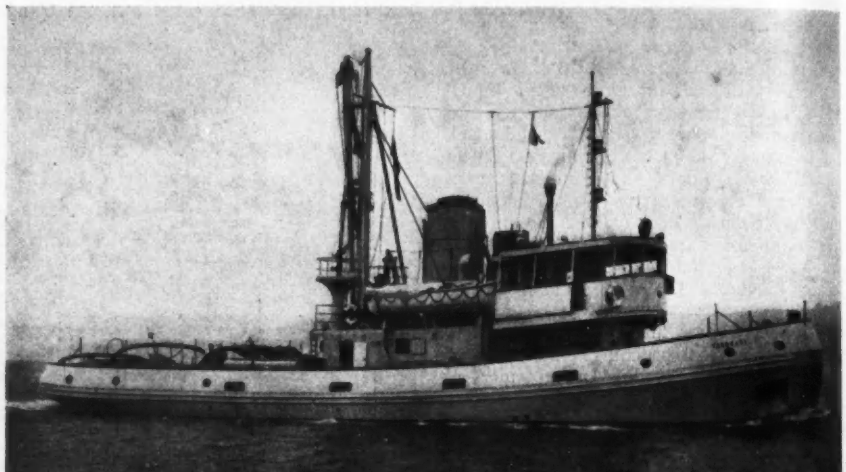


29,650 tons deadweight oil tanker "Solfonn" for Norwegian owners

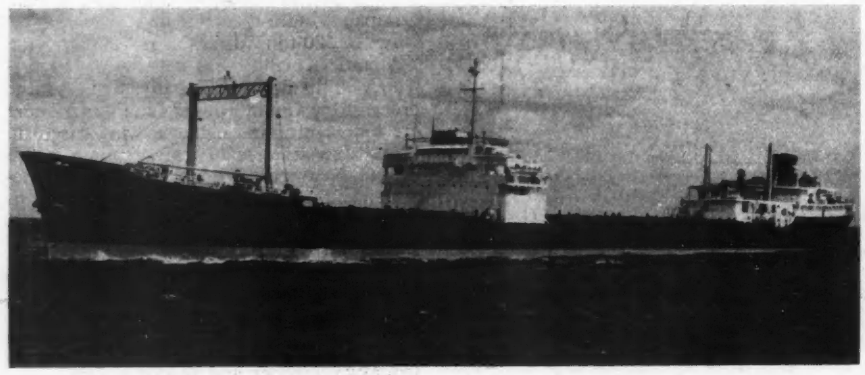
Furness Shipbuilding Company, Ltd., was the "Vivien Louise," for the British Oil Shipping Company, Ltd. This ship, which is shown in our illustration (page 95), has the following particulars: length between perpendiculars, 560ft; breadth, 80ft; depth, 42ft 3in; draught to Lloyd's summer freeboard, 32ft 4in; deadweight 24,850 tons, and a loaded trial speed of 14½ knots. One main cargo room houses three 1000 tons per hour turbine-driven centrifugal pumps and three 150 tons per hour stripping pumps for handling the oil carried in the twenty-seven cargo compartments. Electric power is supplied by two 350kW turbo-generators and one 75kW diesel-driven generator, while Metropolitan-Vickers Electrical Company, Ltd., provided the propelling machinery consisting of a single set of double reduction geared turbines, developing 7300 service shaft horsepower at 100 propeller revolutions per minute. Two Foster-Wheeler "D" boilers provide steam at 450 lb per square inch and 750 deg. Fah. A ship having similar dimensions, the S.S. "Panaghia," was built by the same builders for Porto Alegre Compania Naviera S.A. of Panama, and engined by Richardsons, Westgarth and Co., Ltd.

One of the several oil tankers built and engined by Harland and Wolff, Ltd., to foreign account was the "Solfonn," of 29,650 tons deadweight, for Norwegian owners, which is illustrated herewith. The ship measures 615ft in length by 84ft beam by 49ft deep and has thirty cargo oil compartments and ten 'tween deck ballast tanks. A single shaft arrangement of compound double reduction geared turbines propel the ship and develop 12,500 s.h.p. in service at 112 propeller revolutions per minute, steam being supplied at 450 lb per square inch and 750 deg. Fah. by two Babcock and Wilcox water-tube boilers. Two 800kW, 440V, 60 c/s turbo-alternators provide electrical energy with two 250kW diesel-driven alternators as an alternative source of supply.

We also illustrate the 31,000-ton deadweight ore carrier, "Ruth Lake," which was built at the Wallsend yard of Swan, Hunter and Wigham Richardson, Ltd., for The Iron Ore Transport Company, Ltd., of Canada. There are three ore holds on the centre line, each served by three hatches and bounded by sloping longitudinal bulkheads, the main particulars being as follows: length between perpendiculars, 630ft; breadth, 87ft; depth, 45ft 6in, and service speed 14¾ knots. Four turbine-driven horizontal centrifugal pumps and four stripping pumps serve the wing water ballast compartments. The Wallsend Slipway Engineering Company, Ltd., constructed the main propelling unit, consisting of a single set of geared turbines, of 12,500 service shaft horsepower at 105 propeller revolutions per minute, supplied with steam at 600 lb per square inch and 850 deg. Fah. by two Foster-Wheeler "D" boilers. Power for the auxiliary machinery and ships' services is supplied by two 500kW geared turbine-driven alternators and one emergency 150kW diesel-driven alternator. A smaller ore carrier, the "Redcar," of 15,400 tons deadweight and a service speed of 11½ knots, was handed over to the North Yorkshire Shipping Company, Ltd., by Smith's Dock Company, Ltd. The ship is propelled by a four-cylinder Hawthorn-Doxford oil engine of 4450 b.h.p. Three other tankers, including the "Spyros Niarchos," which was described in THE ENGINEER of June 15, 1956, were illustrated on Plate 10 in our issue of January 11.



Twin screw tug "Takoradi"



31,000 tons deadweight ore carrier "Ruth Lake" for Canadian owners

CROSS-CHANNEL AND SMALLER CRAFT

The "Duke of Lancaster," described in our issue of August 31, 1956, and the "Scillonian," a description of which appeared in our issue of May 25, 1956, were illustrated on Plate 11 in the January 11 issue. The all-welded M.V. "Bonavista," which was specially designed for passenger and cargo service on the Newfoundland coast was completed by Hall, Russell and Co., Ltd., for Canadian National Railways. Accommodation is provided for fifty first-class passengers in two, three and four-berth cabins and forty second-class passengers in four and six-berth rooms, and the ship carries a deadweight of 1000 tons on a length between perpendiculars of 199ft by 35ft beam by 19ft 6in depth. There are three cargo holds served by 3-ton derricks and electric winches and electric power is provided by two 100kW diesel-driven generators and a 50kW auxiliary generator. The ship is propelled by a Fairbanks-Morse opposed piston, non-reversing diesel engine of 1280 b.h.p., driving the propeller shaft through reduction gearing and a hydraulic coupling. A sister ship, the "Nonia," was also completed by the same builders.

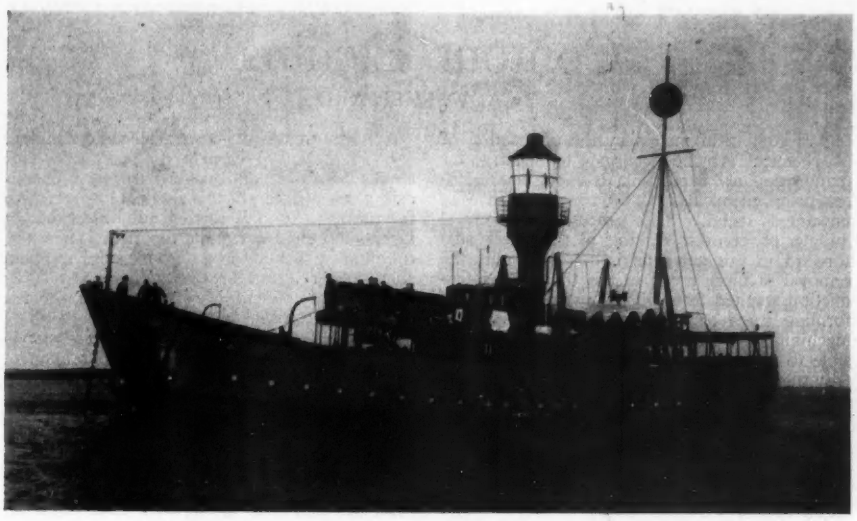
John Lewis and Sons, Ltd., constructed a number of trawlers during the year, including the "Kelso Paton," and "Duff Paton," for the Ardrossan Trawling Company, Ltd. These ships have a length overall of 130ft by 25ft beam by 12ft deep, a tonnage of 274

gross and a fishhold of 6400 cubic feet capacity. The 150 b.h.p. trawl winch has barrel capacities of 1000 fathoms of 2¼in warp and is supplied by a 121kW diesel driven generator. Other electric power is provided by one 20kW and one 10kW diesel-driven generators, and a Mark M.44M British Polar diesel engine developing 640 b.h.p. at 250 r.p.m. forms the main propelling machinery. A much larger trawler, the "Portia," was completed by Smith's Dock Company, Ltd., to the order of Hellyer Brothers, and is fitted with diesel-electric propulsion machinery supplied by the English Electric Company, Ltd. Care has been taken in the design to reduce the danger of loss of stability due to the formation of ice, including the fitting of a bipod mast and the provision of fishing gear on one side only. The ship has a length between perpendiculars of 190ft, a breadth moulded of 34ft 6in, a depth moulded of 17ft 10in, a tonnage of 883 gross, a fish room of 17,300 cubic feet capacity, and a speed of 15 knots. The machinery consists of 850V d.c. propulsion motor of 1500 s.h.p. at 160 r.p.m., supplied with power by three generators, including one 467kW generator driven by an eight-cylinder diesel engine, and two 357kW wing generators, each driven by a six-cylinder diesel engine. All the diesel engines are turbo-charged and on top of each generator is a 60kW chain-driven auxiliary generator. Another trawler, the "Pioner," was shown on Plate 11 in our January 11 issue, and described in our issue of January 27, 1956

A large number of tugs were delivered during the year and among the smaller craft was the Manchester Ship Canal tug "Sabre," described in our issue of September 7, 1956. Built by P. K. Harris (Shipbuilders), Ltd., the tug is of "Hydroconic" construction, and has a length between perpendiculars of 88ft by 24ft 4in breadth moulded, and can exert a pull of 17 tons when going ahead and 10 tons when pulling astern. Propulsion is by two Ruston Mark 6V9BXM six-cylinder diesel engines, each having a continuous rating of 645 b.h.p. and driving through a Hindmarch M.W.D. oil-operated reverse reduction gear. In addition to the above, the tug "Atherfield," which was described in THE ENGINEER of June 1, 1956, was illustrated in Plate 11 in our issue of January 11.

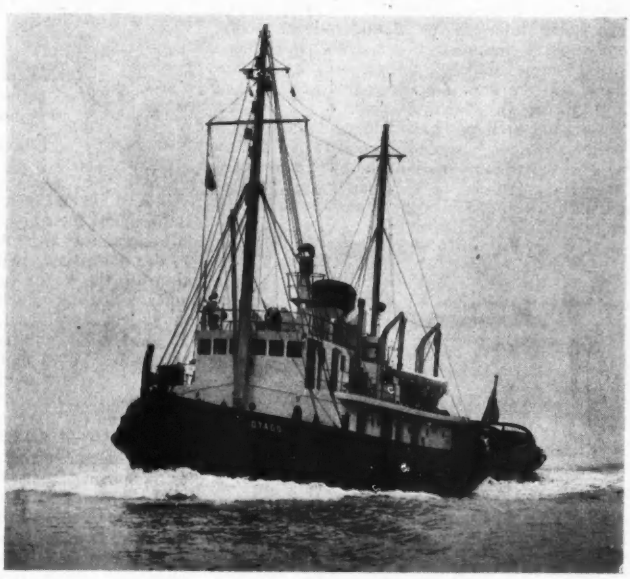
The Crown Agents for Overseas Governments and Administrations took delivery of the tug "Takoradi," which was built by Philip and Son, Ltd., and engined by Plenty and Son, Ltd. On trial a free running speed of 10·6 knots was attained and a bollard pull of 16·2 tons recorded. The main dimensions are: length between perpendiculars, 105ft; breadth, 28ft 9in; depth, 14ft; and propulsion is by two sets of handed triple-expansion engines, each of 400 i.h.p. at 120 r.p.m., and driving an 8ft diameter propeller in a Kort nozzle. A description of the ship, which is seen illustrated on page 96, appeared in THE ENGINEER of October 5, 1956.

One of the larger tugs was the twin-screw "Otago," which we illustrate and which was built and engined by Lobnitz and Co., Ltd., for the Otago Harbour Board. The ship has a length between perpendiculars of 136ft by 35ft beam by 15ft 6in depth, and is powered by two totally enclosed steam engines having cylinder sizes of 13½in, 23in and 36in by 24in stroke, and taking steam at 250 lb per square inch from two Babcock and Wilcox water-tube boilers. Each engine develops 875 i.h.p. at 156 r.p.m. On trial a speed of 13·5 knots was attained and the tug can exert a bollard pull of 20 tons. Extensive fire-fighting and salvage equipment is installed, including a Merryweather fire and salvage pump of 2000 gallons per minute capacity, and foam-making equipment able to produce 1000 gallons per minute.



Lightship "Flame" for the Commissioners for the Port of Calcutta

Among the special-purpose ships completed during the year was the lightship "Flame," which can be seen in our illustration and which was built to the order of the Commissioners for the Port of Calcutta for service at the Sandheads and Western Channel entrance of the River Hooghly. The ship, the dimensions of which are length overall 134ft, beam 26ft, and depth 15ft, was built by J. Samuel White and Co., Ltd., to the designs of Rendel, Palmer and Tritton, and is equipped with a revolving Cata-dioptic light of 158,000 candle power. Three independent diesel-driven generators supply the necessary power, and the lantern and optic were provided by Stone Chance, Ltd. An emergency vaporised oil light is fitted and has an intensity of 53,000 candelas, which enables the full range of 11 miles to be maintained.



Twin screw tug "Otago" for the Otago Harbour Board

A number of dredgers entered service last year, including the "Samuel Armstrong," built by Henry Robb, Ltd., and illustrated on Plate 11 in our issue of January 11. The same builders also completed the motor grab hopper dredger "Annahda," for the Crown Agents for Overseas Governments and Administrations for operation in the seaports of Libya. The ship has a length overall of 110ft, a breadth moulded of 29ft, a depth moulded of 10ft 6in, a loaded speed of 8·5 knots, and a hopper capacity of 5500 cubic feet on a mean draught of 9ft. For dredging there is a Priestman grab dredging crane having a maximum grabbing radius of 30ft and capable of working to a depth of 50ft below water level. One Crossley two-stroke diesel engine developing 420 b.h.p at 340 r.p.m. forms the main propulsion unit. Lobnitz and Co., Ltd., completed the dual-purpose, multi-bucket dredge and rock breaker "Amanful" for work at Takoradi. The dredging gear is designed to give an output of over 200 tons per hour when working in free-getting material, and the 10-ton rock-breaking attachment can operate to a depth of 60ft below water level.

PLYMOUTH "B" POWER STATION EXTENSION.—The Minister of Fuel and Power has consented to the extension of the C.E.A. Plymouth "B" power station. Two 60MW generating sets will be added (bringing the installed capacity of this station up to 214·5MW) with two associated boilers, each having an evaporative capacity of 550,000 lb of steam an hour.

DIRECT DRIVE ENGINE.—For rotary grass cutters, a single-cylinder, 98 c.c., two-stroke engine has been put into production by the Villiers Engineering Company, Ltd., Marston Road, Wolverhampton. The forged crankshaft is vertical and bolts directly on to the cutter; the cylinder is light alloy, with a cast iron liner, and fan cooled. A recoil starter is fitted on top of the self-contained engine unit, which has a governor controlled horizontal carburetter and oil-wetted air cleaner. The output of the Mark 7F is 1·28 b.h.p. at 3000 r.p.m. and 1·4 b.h.p. at 3500 r.p.m.

Contour Etching*

By A. W. SHEPPARD

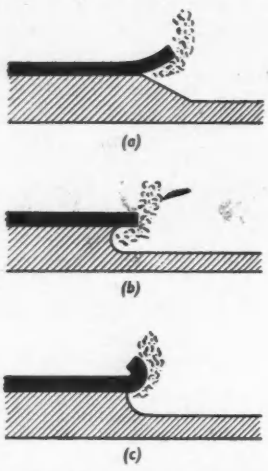
THE etching of metals by the application of chemicals is by no means new to industry; for many years now, in pickling, descaling and photogravuring, chemicals have been used to etch away unwanted metal. The process of chemical milling or contour etching is the latest step forward in this same field, but it permits the removal of more metal in less time. Its introduction resulted from difficulties encountered in forming sheet to the required contours after machining; with contour etching it is now possible to form sheet to the necessary shape and then to etch or mill the geometric reliefs dictated by design requirements. Practice, however, has shown that the process has many other virtues and the chief of these can probably be summarised as follows :—

(1) A considerable economy in machine tool requirements.
(2) A saving in weight which the designers have been quick to exploit.
(3) Elimination of a number of detail tools.
(4) Simplified paper work control of a job in that one process sheet, one job card, tool card, &c., is all that is necessary for what would otherwise be a component comprised of several separate items, each with its own paper work.

Depths of a ¼in are common in this country, although depths of more than 1in are possible at the present time.

Whilst the technique may differ between individual companies, basically the process consists of four stages and I will outline the procedure followed by Saunders-Roe, giving examples of the production specimens produced with, I hope, sufficient information for a comparison to be drawn between this new method and other means of manufacture.

Although etching by alkaline, acid and electrochemical means has been applied to aluminium alloys, magnesium, titanium, copper, and steels, including stainless, in this paper I shall deal primarily with the procedure employed for the etching of aluminium alloys, as it is in these



(a) Defective resistant coating being lifted off the surface of the sheet due to poor adhesion, or due to stiffness of resist resulting in flapping causing peeling.
(b) Resistant coating too stiff, causing gas trapping, and so inhibiting etching.
(c) Correctly formulated resist giving controlled radius at edge.

Fig. 1

materials that most of our more interesting components have been produced.

Description of Process

This consists basically of four stages, as follows :

(i) Pre-treatment cleaning of material.
(ii) Application of resistance medium (known as "masking").
(iii) Etching.
(iv) Post-treatment—neutralising and cleaning.

(i) *Pre-treatment Cleaning of Material.*—This entails degreasing and pickling to give a chemically clean surface which is also suitably receptive for the resist, and is carried out by degreasing in trichlorethylene vapour for twenty minutes, followed by pickling in a chromic-sulphuric acid solution for a further twenty minutes. After this, the component is water washed for ten minutes in both cold and hot water.

(ii) *Application of Resistant Medium—"masking."*—Prior to applying the resist, the component must first be covered on the surface to be worked with a strippable coating over which is placed a stencil defining the contour of the area to be etched. A knife is then traced around the periphery of the stencil to cut the coating which is peeled off in the areas where etching is not required. The component is next sprayed with a standard aircraft etch primer to ensure complete adhesion of the resist, after which it is stoved for fifteen minutes to remove solvents.

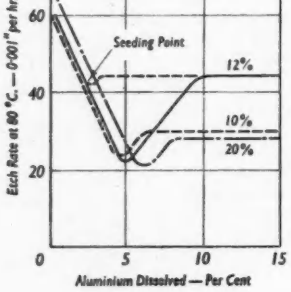


Fig. 2—Etching

The component is now ready for the application of the resist—a polyamide cured epoxy surface coating which is sufficiently flexible to allow gases produced during etching to escape. Examples of edges produced by badly formulated resists are shown in Fig. 1 (*a*) and Fig. 1 (*b*); Fig. 1 (*c*) shows a good edge.

After spraying on the resist the item is stoved in an oven for thirty minutes at 120 deg. Cent., or, alternatively, by infra-red lamps.

Finally, the strippable coating is removed, thus exposing the areas to be etched.

(iii) *Etching.*—Etching is carried out by placing the component in a hot alkaline solution for a specified time to remove the metal in the unmasked areas. The bath is a 12 per cent sodium hydroxide solution modified by bringing the aluminium content of the solution to 2·5 per cent and seeding with aluminium oxide to give a constant etch rate of 0·045 per hour at a fixed temperature of 80 deg. Cent. (see Fig. 2). The reaction between the sodium hydroxide and the aluminium may be represented by the following equation :

$$2NaOH+2Al+2H_2O \rightarrow 2NaAlO_2+3H_2\uparrow$$

Sod. Hydroxide, Aluminium, Water; Sod. Aluminate, Hydrogen

The sodium aluminate, which has a depressing effect on the etch rate, is converted to alumina which is precipitated and removed as a sludge by centrifuging—sodium hydroxide being regenerated, a constant etch rate is achieved. The hydrogen generated during the reaction should be removed by venting. The graph (Fig. 3) shows the behaviour of new etching solutions of various strengths in the unmodified condition, which emphasises the importance of temperature control and shows the etch rate.

It should be mentioned here that if stepped etching is required (necessitating progressive masking) provided the procedure outlined under the headings (ii) and (iii) is carried out right away, the pre-treatment described may be dispensed with.

(iv) *Post-treatment—Neutralising and Cleaning.*—This involves a cold water wash for five minutes, followed by immersion of the component in a cold 10 per cent to 30 per cent nitric acid solution for five minutes to remove the "smuts" and neutralise. A further water wash, entailing a cold and hot rinse for ten minutes, is followed by the final operation of removing the resistant coating by submerging the component in a suitable paint remover for ten minutes.

The component should then be washed for five minutes, dried and surface protected as for a machined item, i.e. anodised or lanoline coated.

The surface finish is inspected against master samples and these are in two grades :

Grade 1.—Is the equivalent of the finish produced on an age-hardened plate and is free from blemishes; this finish is only insisted on where the fatigue life is of paramount importance.

Grade 2.—Finish is similar to that obtained by etching plate in the solution treated condition and is the minimum standard which can be accepted where Grade 1 has not been specified on the production drawing.

Application, Comparative Times and the Weight Factor

Before referring to specific examples with the approximate times taken to produce them as compared with other methods of manufacture, it will be appreciated that there can be an initial saving in plant requirements, due to the fact that, within the limits of the etching tank available, several components may be etched simultaneously.

A panel which, by normal machining methods, took 15 hours to produce, by contour etching required only four-and-a-quarter hours. A fabricated component, consisting of two plates flush riveted together, took a total time of five-and-a-quarter hours to manufacture, whereas by contour etching the time taken was four-and-three-quarter hours. From this particular specimen, too, yet another point in favour of contour etching emerges—that of weight saving. It will be appreciated that an integrally constructed component of this nature is very much stronger than a fabricated item; therefore, by decreasing the gauges of material, a reduction in weight for the same strength may be obtained.

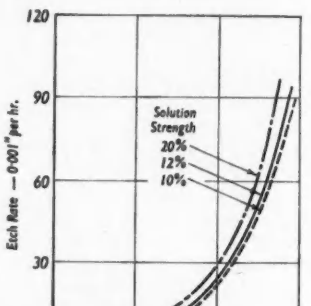


Fig. 3—Behaviour of new etching solutions of various strengths in the unmodified condition

A panel with varying depths, which it would be impracticable to machine from the original plate of 0·064in, as 75 per cent of the skin is only 0·01in thick, with a leading edge of 0·036in, was produced by contour etching in six hours. Taper milling by chemical means is done by gradual immersion or withdrawal at a predetermined rate from the etching solution. This was achieved by first tapering the plate, then reversing the direction of entry and tapering the pockets after remasking.

Physical and Mechanical Effects

Materials which are age-hardened give a much finer surface finish than those in the solution treated condition. This is probably due to the greater rate of differential attack on the softer material; also the finish on the copper-based

* Paper presented at fifth Conference of Southern Section of Institution of Production Engineers, on "Problems of Aircraft Production," January 9, 1957. Abridged.

alloys is superior to that obtained in those containing a high percentage of zinc, such as DTD.687, due to the zinc being more susceptible to attack by sodium hydroxide.

Examination by high magnification has revealed that in materials to specifications such as L.72, L.73, and DTD.687, reduced in thickness by contour etching with the sodium hydroxide solution, there is no intergranular attack or modification to the structure below the etched surface. With L.65 it was found that, the deeper the etching was taken, so pitting increased in the direction of the end grain.

A section through an L.65 block etched to a depth of 1in showed that although the majority of the fissures had the rounded bottom of chemical attack, there were signs of stress corrosion cracks in one or two. This, of course, would affect the fatigue life of a component, but, as they are only of the order of 0·030in deep, they could possibly be polished out.

Bending fatigue tests on specimens, carried out on materials in the "as received," machined, and contour etched conditions, indicate that the number of loading cycles to failure of specimens produced by contour etching is of the same order as that for machined specimens.

Discussion

Mr. R. E. Mills queried whether the method of cutting with a knife through the sprayed film did not introduce stress raisers, whether washing completely removed the alkali, and what surface finish was attainable. He was told that practised operators could cut round the template without marking the metal, and that jobs done thirty months ago had shown no corrosion since. On age-hardened plates a finish of 24 micro-inches was possible.

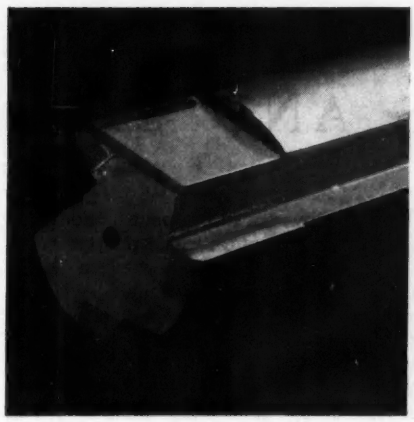
Mr. S. G. Nash raised the question of processing steel and titanium. The lecturer remarked that steel, titanium and magnesium must be etched with acid, an exothermic process. For titanium, hydrofluoric acid or—to avoid hydrogen embrittlement—nitric acid had been used.

In answer to further questions, it was explained that the edges of the sheet were protected by tape, and that components were preferably laid horizontally in the tank to avoid differential trapping of gas at the edges. The etch-resistant film did not dry until stoved, and it had been possible to develop a compound that assumed a uniform thickness after spraying.

During a debate on the possibility of making large thin panels of magnesium by precision casting, by rough casting and chemical milling, or by welding flanges and stiffeners on to plate, Mr. Sheppard observed that castings of magnesium could be etched, whereas porosity prevented the processing of other light alloy castings.

Reamers for High-Tensile Steels

Particulars have been received from Short Brothers and Harland, Ltd., Belfast, of an interesting reaming technique which has been developed to provide an economical, quick and consistently accurate method of finishing holes to size in high-tensile steel components such as are used in modern aircraft construction. The firm found that with these materials the normal practice of finishing such holes by standard reamers was relatively slow and tool maintenance costs were high. The problem was studied by Mr. F. A. Menelaus, the chief tool development engineer of the firm, who decided to investigate the possibilities of a tool based upon the design of the gun drill which has been used for many years for the production of long accurate bores in gun barrels and similar work.

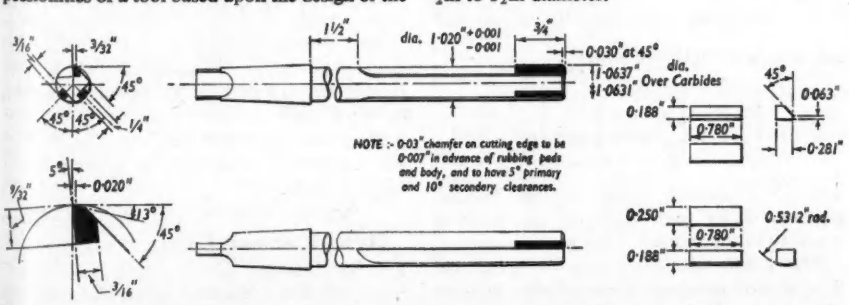


End of reamer showing the tungsten carbide cutting insert and two support pad inserts. The flutes to the support pads ensure an adequate flow of coolant and the larger flute of the cutting insert gives full swarf clearance

As a result of this investigation the design of reaming tool shown in the accompanying drawing was developed and has proved highly satisfactory in service, whilst at the same time being relatively easy to manufacture and maintain. One such tool is now being used for finishing to size holes 1in diameter and 4in deep in twenty-four seconds as compared with the previous time of twenty minutes required with a standard reamer. In another case 1½in diameter holes in S65 (55-ton) steel are being reamed at 600 r.p.m. with a 0·008in per revolution feed with completely satisfactory results.

As can be seen in the illustration, the tool has three straight flutes. At the end of one of the flutes there is brazed a relatively short tungsten carbide cutting insert and complementary tungsten carbide pads are brazed in the other two flutes. The leading edge of the cutting insert has a short chamfer at 45 deg. and it is 0·007in in advance of the ends of the pads which serve to stabilise the tool during the machining operation and ensure that the hole is reamed to consistently accurate dimensions.

The reamer shown in the drawing is dimensioned for a specified 1·0637in to 1·0631in hole, and is a typical tool selected from the range in use at the Belfast works. Over the general range in service, cutting and support inserts are made in a series of sizes adaptable for use when making tools of two or three different diameters. The cutting and clearance angles shown on the drawing are the same for reamers ranging from ½in to 1½in diameter.



Typical reamer for high tensile steels. It has one cutting insert and two supporting pad inserts of tungsten carbide

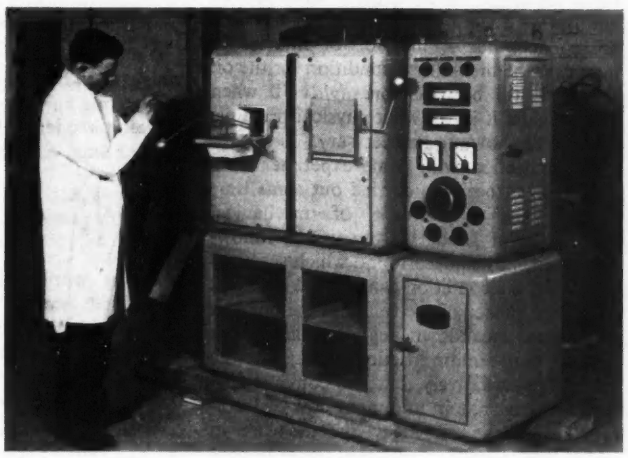
Double Chamber Electric Furnace

A double chamber electric furnace equipment, built by Royce Electric Furnaces, Ltd., Walton-on-Thames, Surrey, for the precision heat treatment of high-speed steel tools, is illustrated below. The furnace has two chambers, each 4½in wide by 4in high and 11in long, arranged side by side. One chamber operates at temperatures up to 1000 deg. Cent for preheating and tempering purposes, and the other at temperatures up to 1350 deg. Cent for hardening purposes. By having the two chambers closely adjoining work can quickly be transferred between them with the minimum heat loss.

Protective atmosphere for the high-temperature chamber is provided by a carborundum muffle which, when heated, produces a neutral atmosphere which prevents scale. This muffle is interchangeable and is stated to have a working life of fifty to one hundred hours. No gas plant or drip feed device is necessary and the chamber is fitted with silicon carbide resistance heating elements, which are easily removed without need for dismantling.

The control gear for the equipment incorporates a voltage regulator for the high-temperature chamber, and an energy regulator for the low-temperature chamber. A temperature indicator instrument is provided for each chamber and, if required, a fully automatic temperature control gear can be supplied.

The doors are so hinged that, when opened, the steel outer face forms a charging plate and the hot face is turned downwards away from the operator. A door insulating plug fits into the entrance vestibule, reducing heat losses to a minimum. The equipment, as illustrated, is supplied as packaged units comprising twin-chamber furnace, control cubicle, floor mounting stand with openwork shelves, and closed tool cupboard.



Electric furnace equipment with two chambers. One chamber operates at up to 1000 deg. Cent. and the other to 1350 deg. Cent.

The Physical Society.—Included in the 1956 *Year Book of the Physical Society* is the text of the Fortieth Guthrie Lecture, delivered by Sir Francis Simon and devoted to a survey of the chequered history of the third law of thermodynamics. Fifty years ago Nernst enunciated his so-called Heat Theorem, which has now become the Third Law of Thermodynamics. At first the theorem was considered mainly as a means of predicting chemical equilibria and was only directly applicable to condensed systems. Later on its formulation as the law of unattainability of absolute zero and its extension to gaseous systems (gas-degeneracy) led to Nernst's claim that it was a law of general validity. More investigations disclosed a number of notable discrepancies and led for a time to its rejection by many physicists. A combination of thermodynamic and statistical reasoning, however, showed that the supposed violations only happened in systems not in thermodynamic equilibrium. The formulation: "The entropy of all factors within a system which are in internal thermodynamic equilibrium disappears at absolute zero" covers all cases without exception and is therefore an expression of a general law of thermodynamics.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents.)

BOUNDARY CONDITIONS IN LUBRICATING FILMS

SIR,—For a number of years now it has been usual to assume in making calculations on the breakdown of the lubricating film on the divergent side of a journal bearing that the mathematical condition to be satisfied is that the pressure gradient in the direction of motion is zero, at the point where the pressure equals the environmental pressure, usually taken as zero. This condition can be shown to follow in some instances from the hypothesis that the shaft takes up the position of minimum potential energy. This argument does not appear to be applicable, however, if an arrangement is envisaged in which the position taken up by the shaft is predetermined—for example, by other bearings—although the load on it will then be unknown. Such a case is not likely to occur in practice, but it may be of interest to inquire if the breakdown condition for the oil film will still be as before $dp/dx=0$ when $p=0$, and, if it is, on what physical principle this can be shown to be necessary.

In connection with some experiments on cavitation in bearings carried out some time ago in the department of mechanical engineering at Leeds University, the following argument has been found which seems to show that the condition can then be regarded as a consequence of the rule that the point at which film breakdown begins is that which results in minimum frictional drag on the shaft or, alternatively, but less convincingly, that which results in minimum flow of lubricant round the bearing. For the case in which side leakage is neglected the argument can be stated very generally.

Reynolds equation in two dimensions gives

$$\frac{dp}{dx}=\frac{6ZU}{h^2}-\frac{12Zf}{h^3} \quad . \; . \; . \quad (1)$$

where p is the pressure, x the distance in the direction of motion, h the film thickness, U the velocity of the moving surface, Z the viscosity of the lubricant and f the flow of lubricant per unit width. With this notation the frictional drag per unit area of the moving surface is

$$s=\frac{ZU}{h}+\frac{h}{2}\frac{dp}{dx}=\frac{4ZU}{h}-\frac{6Zf}{h^2} \quad . \; . \quad (2)$$

in the continuous part of the film.

Now suppose that the film extends from x_1 to x_2 and that the pressure is the same (normally zero) at both ends. Then

$$\int_{x_1}^{x_2}\frac{dp}{dx}dx=6ZU\int_{x_1}^{x_2}\frac{1}{h^2}dx-12Zf\int_{x_1}^{x_2}\frac{1}{h^3}dx \quad . \quad (3)$$

The total frictional drag S per unit width is then

$$S=4ZU\int_{x_1}^{x_2}\frac{1}{h}dx-6Zf\int_{x_1}^{x_2}\frac{1}{h^2}dx \; . \; . \quad (4)$$

There is, however, also a contribution from the part of the film in which the pressure is discontinuous. There is now much experimental evidence—for example, a recent paper by Cole and Hughes[1]—which shows that when breakdown occurs the cavities which are formed extend through the whole thickness of the clearance space and are separated by continuous streams of oil which must be under nearly constant pressure. Under these conditions the drag due to viscosity is easily calculated. The total width of the non-cavitated region per unit width of bearing is given by

$$b=2f/Uh$$

and the drag per unit area is thus

$$s^1=\frac{2f}{Uh}\cdot\frac{ZU}{h}=\frac{2Zf}{h^2} \quad . \; . \; . \quad (5)$$

Thus the total drag in the cavitated region is

$$S^1=2Zf\int_{X_1}^{x_1}\frac{1}{h^2}dx+2Zf\int_{x_2}^{X_2}\frac{1}{h^2}dx \; . \; . \quad (6)$$

where X_1 and X_2 are the terminal values for the bearing surface say $-\pi R$ and $+\pi R$, for the complete journal bearing. Thus the total friction drag, S and S^1, is

$$\bar{S}=4ZU\int_{x_1}^{x_2}\frac{1}{h}dx-8Zf\int_{x_1}^{x_2}\frac{1}{h^2}dx+2Zf\int_{X_1}^{X_2}\frac{1}{h^2}dx \quad (7)$$

Let us restrict attention to the case when x_1 is fixed, because the lubricant is supplied in sufficient quantity to ensure that the film starts at that point. In some types of bearings, for example, immersed partial bearings, x_1 must coincide with X_1.

Then if $\bar{S}$ is to have a stationary value,

$$\frac{\partial\bar{S}}{\partial x_2}=\frac{4ZU}{h_2}-\frac{8Zf}{h_2^2}-8Z\frac{\partial f}{\partial x_2}\int_{x_1}^{x_2}\frac{1}{h^2}dx+2Z\frac{\partial f_2}{\partial x_2}\int_{X_1}^{X_2}\frac{1}{h^2}dx=0 \quad . \quad (8)$$

where h_2 is the value of the film thickness at x_2. But condition (3) must be satisfied at all times, no matter how x_2 varies. Thus

$$\frac{6ZU}{h_2^2}-\frac{12Zf}{h_2^3}-12Z\frac{\partial f}{\partial x_2}\int_{x_1}^{x_2}\frac{1}{h^3}dx=0 \quad . \quad (9)$$

Now multiplying equation (9) by $\frac{2}{3}h_2$ and subtracting from (8) we have

$$\frac{\partial f_2}{\partial x}\left\{h_2\int_{x_1}^{x_2}\frac{1}{h^3}dx-\int_{x_1}^{x_2}\frac{1}{h^2}dx+\frac{1}{4}\int_{X_1}^{X_2}\frac{1}{h^2}dx\right\}=0 \; . \; (10)$$

Thus a stationary value of the friction requires either that $\delta f/\delta x_2=0$ or that the quantity in the bracket is zero.

The latter alternative can be ruled out from the following argument. From equation (3) we can write in place of (10)

$$\frac{\delta f}{\partial x_2}\left[\left(\frac{Uh_2}{2f}-1\right)\int_{x_1}^{x_2}\frac{1}{h^2}dx+\frac{1}{4}\int_{X_1}^{X_2}\frac{1}{h^2}dx\right]=0 \; . \; (11)$$

and then from equation (1)

$$\frac{\partial f}{\partial x_2}\left[\frac{h_2^3}{12Zf}\left(\frac{dp}{dx}\right)_{x=x_2}\int_{x_1}^{x_2}\frac{1}{h^2}dx+\frac{1}{4}\int_{X_1}^{X_2}\frac{1}{h^2}dx\right]=0 \quad (12)$$

But, as has often been pointed out, the condition of continuity of flow requires that at the point of breakdown the pressure gradient is either positive or zero. Since the integrals are positive, it follows that the quantity in the bracket is necessarily positive. Thus $\delta f/\delta x_2=0$.

But if $\delta f/\delta x_2=0$ it follows at once from (9) that $h_2=U/2f$ and hence from (1) that $\left(\frac{\partial p}{\partial x}\right)_{x=x_2}=0$ as required.

This conclusion may, of course, require modification in practice. In some cases surface tension may result in fluid pressures just outside the cavity which vary appreciably at different points in the bearing, and in others the start of the continuous film $x=x_1$ may vary substantially with the lubricant supply pressure.

The concept of minimum drag is, of course, not a new one. The fact that a viscous fluid enclosed within boundaries which move at a known velocity will take up that velocity distribution which implies minimum dissipation of energy was proved by Helmholtz[2] in 1868, and cases in which the principle seems to have been operative in practice have recently been reported.[3] It is perhaps worth noting also that the flow of a viscous fluid is in many respects exactly analogous to the distortion of an elastic solid, and an analogy can be perceived between the view here put forward and Castigliano's well-known second theorem of minimum strain energy.

D. G. CHRISTOPHERSON
Imperial College, London, S.W.1,
November 14, 1956.

REFERENCES

[1] Cole, J. A., and Hughes, C. J., "Oil Flow and Film Extent in Complete Journal Bearings," Institution of Mechanical Engineers, presented February 10, 1956.
[2] Lamb, H., "Hydrodynamics," Sixth Edition, page 618.
[3] Christopherson, D. G., and Naylor, H., "The Promotion of Fluid Lubrication in Wiredrawing," *Proc. I.Mech.E.*, Vol. 169, No. 35 (1955).

F. W. LANCHESTER

SIR,—I am writing a biography of F. W. Lanchester (1868–1946), for which I have been given material by his brother. I shall be very glad to hear from any of your readers who have personal reminiscences of Dr. Lanchester or documents relating to his life and work.

P. W. KINGSFORD
Hatfield Technical College,
Roe Green,
Hatfield, Herts.
December, 1956.

Literature

Notes on Prehistoric and Early Iron in the Old World. By H. H. COGHLAN, A.M.I. Mech.E., F.S.A. Occasional Papers on Technology, 8. Edited by T. K. Penniman and B. M. Blackwood. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 25s. net.

WE often fail to appreciate how recent a thing research into primitive metallurgy is. Professor Henry Louis contributed a noteworthy paper thirty years or so ago, and before him Mr. A. T. Jenkins, of Rotherham, devoted a considerable proportion of his time to studies of early iron and ironworking. Neither of them is referred to in Mr. Coghlan's remarkable book. With the exception of Professor Forbes's monumental work on *Metallurgy in Antiquity*, drawn upon at times by the author, this is, nevertheless, the most informative and admirably documented study of its subject that has hitherto been published, replacing all previous work and bringing the subject fully up to date.

The opening chapter discusses iron ores and ancient mining in a concise and somewhat technical manner, which is no drawback. Chapter II, on the nature of meteorites and the working of meteoric iron, is fascinating, particularly when one has had the opportunity to study the remarkable specimens in the Metropolitan Museum, New York. Early smelting and mechanical working are next discussed, and there are amply illustrated and informative papers on furnaces and fuels, the tools of the smith, the technical art of the smith to about A.D. 1000, and three additional chapters that are rather in the nature of appendices than continuous narrative, dealing as they do with ancient iron's technical terms, an Eskimo knife collected by Sir John Ross, and an examination of specimens chosen by the Pitt Rivers Museum.

No fault is to be found with either the metallurgy or the matter of Mr. Coghlan's book, except that his English is at times a trifle turgid. In case he is not acquainted with it, his attention may be drawn to that admirable publication *Der Schwartze Hephaestus*, by René Gardi, published by the Iron Library at Schaffhausen, which contains probably the most illuminating and vivid photographs of primitive iron smelting and forging to be found in the world. But there are some important gaps in the author's account of the early history of files and saws. For example, he appears not to know the work of Otto Dick on the file and its history, from which it is plain that the Celts had iron files with tangs. Rasps and knife-shaped files, dating from 666 B.C., as well as saws, were discovered by Flinders Petrie at Thebes in Egypt. The Assyrians had iron saws as well as files. Moreover, even before the flint saw made up of flints embedded in a wooden blade there were, and, it is believed, still are, saws made from shark's teeth or even notched shells in the Pacific Islands. The saw is, in fact, one of the oldest tools in the world. The book is bound in paper covers somewhat after the fashion of Newcomen Society publications, but it is beautifully printed on stout paper. The sketches are bold, clear and informative, and the metallographic plates admirable.

Fatigue of Metals and Structures. By H. J. GROVER, S. A. GORDON and L. R. JACKSON. Thames and Hudson, Ltd., 30, Bloomsbury Street, London, W.C.1. Price 35s.

THE authors state, in the preface, that the Battelle Memorial Institute was commissioned by the publications division of the Navy Bureau of Aeronautics to survey the present state of knowledge of fatigue of metals and to prepare the manuscript of this book, which is directed particularly to the designer or engineer with some knowledge of, but limited experience in, fatigue problems; it is intended to provide a summary of present-day information and to provide references to published literature for more complete information. In justice to the authors, this review note commences with the foregoing informed statement of the genesis and objects of this book, for it is an unusual and somewhat curious work which has presented considerable difficulty to a conscientious and would-be kindly reviewer.

The subject is treated in the form of fifteen chapters and three appendices. Thirteen of the chapters deal with the usual main divisions of fatigue phenomena, the others with the special discussions of the fatigue characteristics of structural and machine components, also of composite structures, with reference to design aspects. Within each chapter, the main division is broken down into appropriate aspects which are usually discussed in a purely descriptive treatment : no attempt is made to discuss critically, or even present, all the reliable data now available. This method of personal selection of one or a few examples is, perhaps, justified, provided it is accepted that only a personal view emerges and, therefore, that this book can never be regarded as a standard textbook. In fact, this may be accepted by the authors, for, in many places, the reader is urged carefully to review the literature on the subject ; also, at the end of each chapter, a useful list of references appears which, if drawn almost entirely from U.S.A. publications, does very occasionally contain a reference to foreign research. But the subject is so wide and the literature of the fatigue of metals so vast that one can understand the difficulties encountered in the endeavour to extract general design rules for the whole range of engineering materials of construction—an impossible task. Even so, some of the short cuts are startling ; for example, to find that, in regard to the effect of mean stress, only the modified Goodman relation is discussed, or, again, to be faced with the apparent inference that anisotropy is primarily responsible for the failure to reconcile failure under combined fatigue stresses to one of the classical theories which have been suggested as governing the breakdown of primitive elasticity.

The first appendix consists of some photographs of fatigue failures in service ; the second is a short discussion of the statistical analysis of fatigue data. The third appendix, which runs to 121 pages out of a total of 324, consists of tables of static and fatigue properties of ferrous and non-ferrous metals, with a few data relating to plastics, plastic laminates, wood and plywood ; it must be added that the authors, with commendable candour, felt it necessary to preface the tables with the remark " that it has been impractical to select information on any basis that would warrant its validity."

High-Speed Flight. By E. OWER and J. NAYLER. Hutchinson's Scientific and Technical Publications, 178-202, Great Portland Street, London, W.1. Price 30s.

A BOOK on a technical subject intended to be read by laymen is one, it may be argued, that should not be subjected to the full rigour of technical criticism. We have a certain sympathy with that argument. For it is difficult and perhaps, indeed, impossible to convey in the imprecise language of ordinary speech the very precise meanings of scientific and technical terms. For this reason we prefer not to review this book in any detail. Those who read what we write here will predominantly be technical men. Our impression is that if they read this book they will repeatedly be irritated by loose and even inaccurate statements, designed no doubt to convey some meaning to the layman, and by the omission of matters of deep technical interest and importance, possibly out of the sheer difficulty of conveying to an uninformed mind any impression of their meaning. Whether, despite defects obvious to the technically informed, the book will be valuable to the layman, we are not in a position to say. But we consider that it is not to be numbered amongst those books which must be found in the library of anyone hoping to be fully informed technically.

Books of Reference

Electricity Undertakings of the World : The Electrical Journal Red Book, 1956–57. Edited by Norman H. Codling, D.F.H. (Hons.), A.M.I.E.E. Benn Brothers, Ltd., 154, Fleet Street, London, E.C.4. Price 30s.—The sixty-sixth edition of this work of reference follows the same general design as its predecessor in presenting information about the Central Electricity Authority and Area Boards, the Scottish Boards and electricity undertakings in Northern Ireland and countries overseas. Details are included from 117 localities not previously mentioned in this book. There are seventy-two new entries from India, seventeen from South America and additional data from the Belgian Congo, Canada, the Gold Coast, Iraq, Italy, the Netherlands, Nigeria, Nyasaland, Puerto Rico, Sarawak, Spain, Swaziland, the Union of South Africa, the U.S.A. and the West Indies.

Kempe's Engineers Year Book, 1957. Sixty-second edition. Two Volumes in Case. Morgan Brothers (Publishers), Ltd., 28, Essex Street, Strand, London, W.C.2. Price 82s. 6d. (postage 2s. 6d. extra).—Each of the seventy-nine different sections of this handbook receives the attention of a specialist in that subject, during the annual revision, thus ensuring that the contents are up-to-date. Every year brings with it a number of new materials, new methods and processes, new tools, new testing and metering techniques, new standards, codes, regulations, and tables, and the revision of many existing ones. This information is to be found in *Kempe's*, conveniently arranged and cross-referenced, and readily accessible from the comprehensive index. The work is edited under the direction of the Editor-in-Chief of THE ENGINEER. The 1957 *Kempe's* contains three new items which call for special mention, as well as the additions which have been made in almost every part of the book. There is a completely new chapter, " Gearing," by Dr. H. E. Merritt, M.B.E.; a new section to the chapter on Railway Engineering, entitled " Diesel Locomotives and Railcars " ; a new section to the chapter on Grinding Abrasives, &c., entitled " Blasting Processes and Machinery." Among the additions in other parts of the book are the following : transfer machining processes ; copying lathes ; tool tips ; demagnetisers ; the CO_2 foundry process ; titanium alloys ; nickel alloys ; slotted metal sections ; bearing materials ; " carrying power " of water mains ; pipe-laying, testing and disinfection ; cathodic protection ; pump turbines ; magnetic hardness tests for steel ; optical torsion meters ; metering of liquids. Every effort has been made to bring the information up-to-date, and this new edition of the *Year Book* should prove of great value and assistance to all who have occasion to use it.

Books Received

Maintenance of High-Speed Diesel Engines. Fourth edition. By A. W. Judge, Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 56s.

Electrical Machines : A Book in the Electrical Engineering Series. By A. Draper. Longmans, Green and Co., 6 and 7, Clifford Street, London, W.1. Price 40s.

The Challenge of Change. By Laurence Thompson. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 5s.

Reactor Shielding Design Manual. Edited by Theodore Rockwell. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 45s.

Electrical Engineering (General) (Electrical Engineering Series). By A. T. Dover, F. T. Chapman, F. Brailsford and Harley Carter. Longmans, Green and Co., 6 and 7, Clifford Street, London, W.1. Price 50s.

Engines at the National Boat Show

Both diesel and petrol, outboard and inboard power units, covering a wide range of power, were on view, together with a wide variety of small craft, at the National Boat Show. Many of the engines were exhibited for the first time, while others were examples of well-proved units.

THE third National Boat Show, which opened on January 1 at the Empire Hall, Olympia, and closed on January 12, contained examples of all forms of construction ranging from a 5ft rowing coracle to a lifeboat, the inexpensive to the expensive, and the slowest to the fastest. Also shown were numerous items of equipment representative of deck and other auxiliaries, navigational aids, life-saving gear and other items essential to the operation of small craft.

Several engines of the range manufactured by F. Perkins, Ltd., were shown on its stand, and included a new three-cylinder model, the Mark P3(M), which has been designed for hand starting and is approved by Lloyd's. This four-stroke, three-cylinder in-line diesel engine, seen in our illustration, has a bore and stroke of 3½in and 5in respectively, and an output of 20/30 b.h.p. at 1200/2000 r.p.m., and weighs 1002 lb with direct drive. Cast iron alloys are used for the cylinder block and cylinder head, and the aluminium alloy pistons have three compression and two oil control rings, while the crankshaft, forged from nickel-chrome-molybdenum steel, has heat-treated and hardened bearing surfaces, and is carried in thin wall bearings. The injection equipment includes a fuel pump, a lift pump and a pneumatic governor, and lubrication is by a gear-driven pump which circulates oil under high pressure, the oil being cooled in a water-circulated heat exchanger. Four systems of engine cooling are available and the engine has an installation angle of 15 deg., which allows for a further 3 deg. of trim when the boat is under way. Another exhibit of interest was a Mark P6(M) engine, which was completely submerged in a tank of water and could be started at a touch of a button. The engine was not specially prepared and the installation demonstrated in a practical manner the ability of the engine to operate under adverse conditions likely to be encountered at sea.

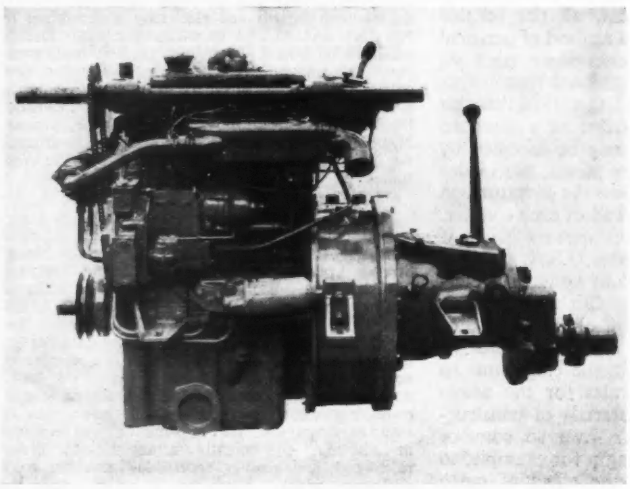
Ruston and Hornsby, Ltd., now manufacture diesel engines which are suitable for powering small craft: the power range is covered by the Mark YBM units of 4 h.p. to 13 h.p., available as one or two-cylinder models, and the YCM models of 16 h.p. to 78 h.p., and having two, three, four or six cylinders. On its stand the company showed a 2YBM engine which develops 13 s.h.p. at 1800 r.p.m., and a 4YCM unit which develops 52 s.h.p. at 1800 r.p.m., and is illustrated herewith, both being four-stroke compression-ignition diesel engines with open combustion chambers and direct injection.

In the YBM engine the crankcase and cylinder block are separate castings, of close-grained cast iron, and the latter is fitted with removable, nitrogen-hardened, wet liners. The cylinder head, also of cast iron, carries the overhead inlet and exhaust valves and operating gear. Three pressure and two scraper rings are fitted to the aluminium alloy pistons, which are anodised on the crown, lands and ring grooves. The connecting-rods, steel stampings of H-section, have steel-backed big-end bearings having the top half copper-lead lined, and the bottom half white-metal lined, while the small end bearings are steel backed and copper-lead lined. Steel-backed, white-metal lined bearings carry the hardened and ground crankshaft, which is a steel stamping and drives the high-tensile cast iron camshaft through gearing. There is a centrifugal governor, an oil-wetted air cleaner, and a single unit " Helix " fuel pump supplying fuel to multi-hole injectors, while lubrication is by a submerged gear pump. A bronze gear-pattern sea water circulating pump is mounted and corrosion plugs are fitted in the cylinder block and head.

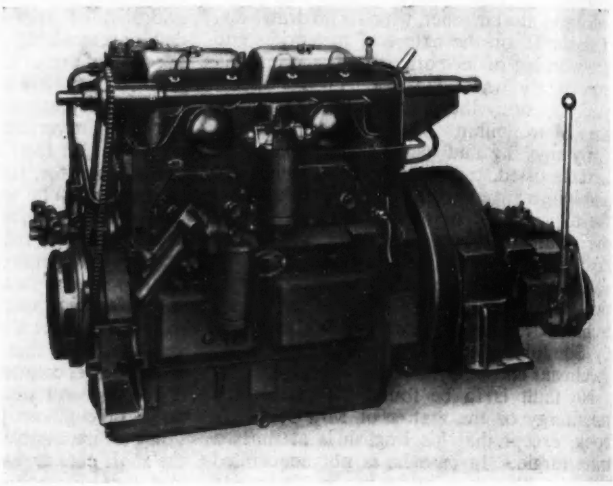
The specification of the YCM is similar to the YBM unit in several respects; however, the crankcase and cylinder are of monobloc construction and the aluminium alloy pistons are completely anodised above the top scraper ring. Another difference is that the connecting-rod big-end bearings are steel-backed, copper-lead lined, as are also the bearings which carry the crankshaft.

On the stand of Morris Motors, Ltd. (Marine Division), a complete range of new B.M.C. marine engines was on view, there being eight engines showing various alternative specifications. The new units exhibited were: the 950 c.c. B.M.C. " Vedette " petrol engine developing 14/20 b.h.p. at 2000/3000 r.p.m.; the 1500 c.c. B.M.C. " Navigator " petrol or vaporising oil engine developing 25/35 b.h.p. at 2000/3000 r.p.m.; the 2·2-litre B.M.C. " Commander " diesel engine, developing 22, 31 and 46 b.h.p. at 1500, 2000 and 3000 r.p.m. respectively, and the 3·4-litre B.M.C. " Commodore " diesel engine, developing 38, 48 and 52 b.h.p. at 1500, 2000 and 2400 r.p.m. respectively. All are four-cylinder models having overhead valves, detachable cylinder heads and sumps.

Our illustration shows the " Vedette," which has a bore of 62·94mm, a stroke of 76·2mm, a compression ratio of 7·2 to 1, and weighs 395 lb, with electric starting and direct drive. The cylinders are cast integral with the crankcase in grey iron and the sump is of light cast iron, while the pistons, of split-skirt pattern, are of aluminium alloy, and have three compression rings and one scraper ring. There is a three bearing forged steel camshaft, and three replaceable steel-backed white-metal bearings carry the forged steel crankshaft. Valves of silicon-chrome steel and guides of cast iron are fitted. Lubricating oil at about 60 lb per square inch is fed to all the principal bearings by a coaxial non-draining pump, and at a lesser pressure to other parts. Two cooling systems are offered, either by direct sea water cooling or by a closed circuit fresh water system having a header tank and a keel cooler, and there is a " Jabsco " water pump having a neoprene impeller. The updraught Solex carburetter is spill-proof up to an angle of 30 deg. in any direction, while the maximum installation angle of the engine is 10 deg. For starting there is a 12V starter and dynamo and also a raised starting handle. The specification for the B.M.C. " Navigator " is, in most respects, similar to that of the " Vedette."



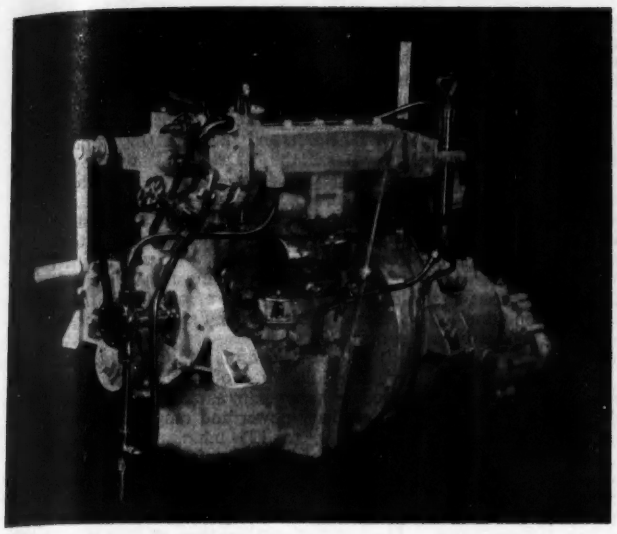
Perkins P3(M) three-cylinder four-stroke engine having an output of 30 b.h.p. at 2000 r.p.m.



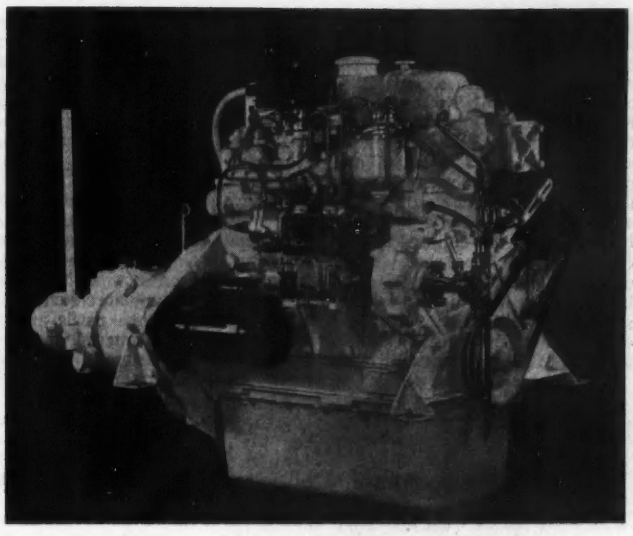
Ruston " 4YCM " diesel engine with Parsons reverse/reduction gear

The larger of the two diesel engines, the " Commodore," which we illustrate, has a bore and stroke of 95mm by 120mm and 16·5 to 1 compression ratio and with direct drive weighs 1020 lb. Wet pattern cylinder liners are fitted to the cylinders, which are cast integral with the crankcase, and there is a light cast iron sump. Three compression rings and two oil control rings are fitted to the aluminium alloy pistons. The forged steel crankshaft is carried in five steel-backed copper-lead bearings and the five bearing camshaft is also of forged steel. The four-hole fuel injectors are supplied by a C.A.V. fuel pump, fitted with a pneumatic governor, and a fuel lift pump provided with a priming lever. A Hobourn Eaton eccentric rotor pump, crankshaft driven, supplies lubricating oil at high pressure to bearings and at lesser pressure to other parts, and the system includes a full flow external filter and a filter pick-up in the sump. A " Jabsco " water pump with neoprene impeller is supplied and the cooling system can be by sea water or by a closed fresh water circuit. The reverse gear is self-locking in ahead and astern positions and both 2 to 1 and 3 to 1 reduction gears are available. Electric starting is provided. The smaller diesel engine, the " Commander," is generally similar to the " Commodore," but has dry cylinder liners and three main crankshaft bearings.

Two diesel and two petrol engines of the range manufactured by Henry Meadows, Ltd., were shown, and on the same stand the Bergins Company, Ltd., displayed a number of the company's products, including the new Kelvin diesel P2 engine. This unit, seen in our illustra-



B.M.C. "Vedette" four-cylinder petrol engine of 14 b.h.p. at 3000 r.p.m.



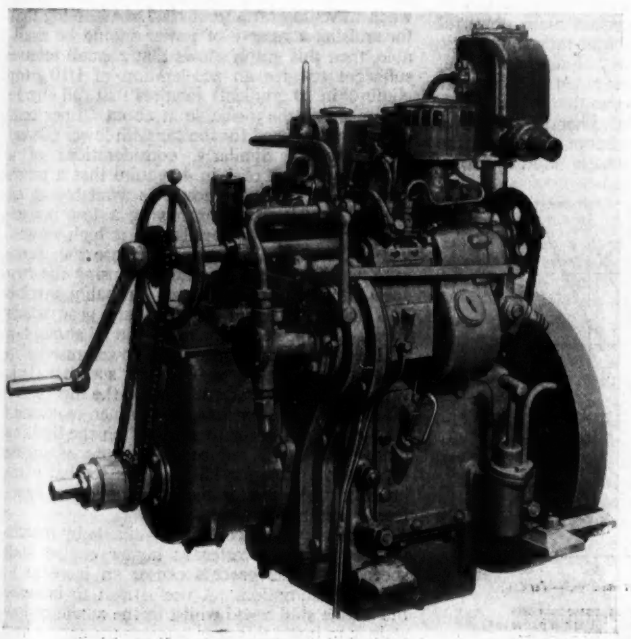
B.M.C. "Commodore" four-cylinder diesel engine developing 38 b.h.p. at 1500 r.p.m. and 52 b.h.p. at 2400 r.p.m.

tion, is a hand-starting, direct injection, two-cylinder, four stroke engine having a bore of 3½in and a stroke of 4in, a compression ratio of 16·5 to 1, and an output of 10 b.h.p. at 1500 r.p.m. Cast iron is generally used in the construction and the cylinders and crankcase are cast in a monobloc unit. Wet cylinder liners are fitted and a single cylinder head. The aluminium alloy pistons have three compression and two oil control rings, and the connecting rods, which are stampings of carbon steel, have thin-walled bronze-lined small end bushes and thin-wall copper-lead lined big end bearings. Two steel-backed white metal bearings take the alloy steel crankshaft, while the carbon steel camshaft runs in two bushes. C.A.V. fuel injection equipment is mounted and provision made for a fuel lift pump and lubrication of the engine bearings is by a forced feed system. Direct sea water cooling is standard but fresh water cooling with a heat exchanger can be fitted and with both versions the sea water pump is a flange-mounted rotary, self-priming gear-driven unit. A reverse gear of standard Kelvin pattern, using cone clutches, is included and the engine, which weighs 605 lb, has a fuel consumption of 0·42 lb per b.h.p. per hour.

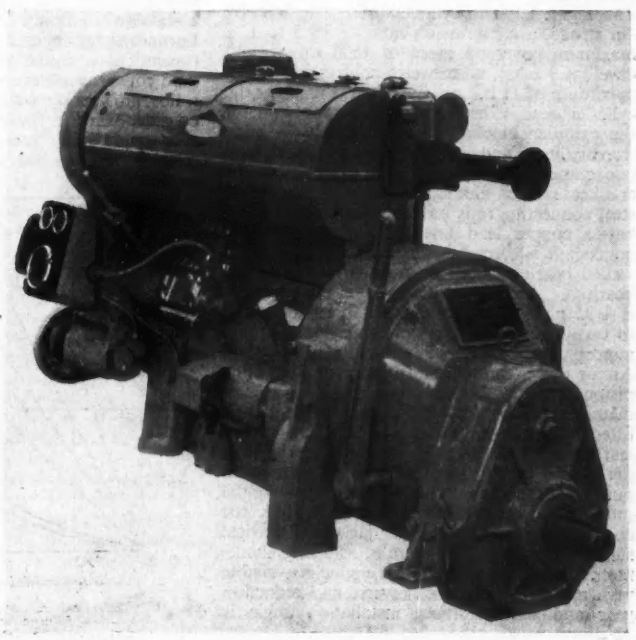
Five engines were exhibited by Ajax Marine Engines, Ltd., and included the four-cylinder, direct injection, 30/40 h.p. Albion "Albacore," the 65 h.p. Albion "Albatross," the six-cylinder, 65/90 h.p. Leyland "Amazon," the 115/150 h.p. six-cylinder Leyland "Atalanta," and the new 200 h.p. Ajax "Argosy." This engine, which incorporates the Leyland/Albion EN900, direct injection, overhead valve, four stroke engine, has six cylinders of 5½in bore by 6½in stroke, a compression ratio of 15·1 to 1, and develops a maximum of 200 b.h.p. at 1800 r.p.m. and a b.m.e.p. of 105 lb per square inch and 170 b.h.p. on a twelve-hour rating. The crankcase is of cast iron and integral with the cylinder block, which is fitted with wet liners; this material is used for the cylinder heads, each of which covers three bores. Three compression rings, the top one chromium-plated, and two scraper rings, are fitted to the aluminium alloy pistons and the connecting rods, which are polished alloy steel stampings, have a phosphor-bronze bush at the small ends and steel-shell, copper-lead, indium coated big end bearings. Seven similar bearings support the nitrided forged alloy steel crankshaft, while the camshaft also has seven bearings.

Fuel injection is by C.A.V. equipment, incorporating a triple C.A.V. paper element filter, and a diaphragm pattern lift pump. Integral with the injection pump is a mechanical all-speed governor. A gear pattern pump supplies lubricating oil at pressures ranging from 25 lb to 55 lb per square inch at 600 to 1800 r.p.m., respectively. The wet sump has an oil capacity of 9 gallons and is suitable for installation at a rake up to 1 in 7. A gear-driven centrifugal pump, with self-adjusting carbon gland, circulates the cooling water in the closed system. Two 24V cradle-mounted axial starter motors and a dynamo are fitted. Fuel consumption is approximately 0·38 pint per b.h.p. per hour and the unit has a weight of about 2·25 tons.

Various examples of single and twin-cylinder air cooled diesel engines, and also a twin-cylinder water cooled model, were shown on the stand of Petters, Ltd. Also exhibited was a two-cylinder air cooled Petter-McLaren engine which develops 16 b.h.p. at 1200 r.p.m. and 24 b.h.p. at 1800 r.p.m., and a four-cylinder model. The latter, shown in the photograph which we reproduce, is a four stroke, direct injection, air cooled compression ignition engine developing 32/48 b.h.p. at 1200/1800 r.p.m. Cylinder bore and stroke are 4·5in and 4·33in, respectively,

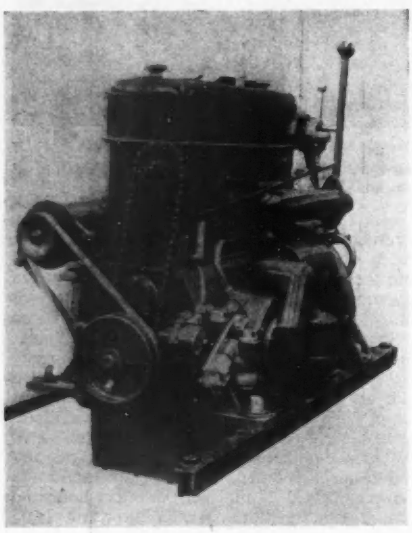


Kelvin "P2" diesel engine of 10 b.h.p. at 1500 r.p.m.



Petter-McLaren "PD4M" air-cooled diesel engine rated at 48 b.h.p. at 1800 r.p.m.

and the compression ratio 16 to 1, while the b.m.e.p. is 77 lb per square inch and the fuel consumption is 0·43 lb per b.h.p. per hour at 1800 r.p.m. The crankcase, separate cylinders and cylinder heads are all of cast iron and the latter has directional ports to ensure efficient combustion. Aluminium alloy pistons, having a hemispherical bowl in the crown and three compression and two slotted oil control rings, are used, and the forged steel connecting rods have small end bushes of phosphor bronze and steel-backed thin-wall copper-lead lined big end bearings. The crankshaft is underslung and carried in five bearings. A lift pump and a block pattern fuel injection pump form the fuel system, and lubrication is by a gear pump which draws oil from the wet sump and delivers it under pressure to the bearings and rocker gear. The



Stuart Turner 9 b.h.p., two-stroke, two-cylinder diesel engine

engine is fitted with a reverse gearbox and a 2 to 1 reduction gear as standard, but alternatives are available.

Stuart Turner, Ltd., displayed on its stand examples of the range of engines manufactured by the company, including 1½ h.p., 4 h.p. and 8 h.p. petrol two-stroke units, and the 9 b.h.p. two-stroke, compression ignition Mark H2MR diesel engine, which is shown in our illustration. The engine has two cylinders of 2·75in bore by 4in stroke, a compression ratio of 16·5 to 1, a maximum governed speed of 1500 r.p.m., and develops 9 b.h.p. on a twelve-hour rating, and a maximum of 11 b.h.p. Cast iron is used for the cylinder head, exhaust manifold, sump, and for the cylinder block, which is fitted with alloy iron dry liners, and also for the pistons which have one scraper and four compression rings, while the crankcase is of aluminium alloy. The forged steel connecting rods have big ends with loaded halves copper lead lined, the alloy cast iron crankshaft is carried in three steel-backed, thin-walled bearings, and the camshaft runs in ball bearings. At full throttle the fuel consumption is 4·75 pints per hour and the fuel is delivered to two-hole nozzle injectors, which open at 170 atmospheres, by a C.A.V. pump and a lift pump. An air pump consisting of two aluminium alloy pistons yoked together and driven by a gun-metal connecting rod from the crankshaft is fitted, with air valves having beryllium copper leaf springs. Lubrication oil pressure is 60 lb per square inch from a submerged gear pattern pump and there is a drain pump for emptying the pump. A Stuart plunger pump delivers the cooling water to the cylinder jacket. Electrical starting is arranged but there is a starting handle fitted for emergency use. The engine is available with reverse gear or with reverse and reduction gear and the maximum installation angle is 12 deg.

The Coventry Victor Motor Company, Ltd., displayed many examples of its vertical single and horizontally opposed twin-cylinder, four-stroke power units ranging from 2½ h.p. to 22 h.p., and also four-cylinder horizontally opposed units. Vaporising oil conversion equipment was on show and a number of petrol driven outboard engines having horizontally opposed twin-cylinders.

Besides exhibiting examples of its "Pike" and "Porbeagle" diesel engines and the "Goosander," "Merganser" and "Peregrine" air-cooled engines, the Parsons Engineering Company, Ltd., also showed a range of gear pumps and marine reverse gears. Included among these was the reverse reduction type "D" gear, in which the ahead drive is taken through a multiplate clutch actuated by a sliding cone and adjustable pawls, and in the ahead condition the whole internal mechanism revolves as a unit. The astern drive is obtained through a bevel gear train enclosed within the bevel case, which is held stationary, and the bevel pinions rotate on their axis and so reverse the rotation of the shaft. The reduction gear is a self-contained unit with ratios 2 to 1 or 3 to 1. Both reverse and reduction gears are designed to transmit full power ahead and astern at 1½ h.p. per 100 r.p.m. to 3000 r.p.m., the torque being 80 lb-ft.

Arthur Bray, Ltd., besides showing runabouts, exhibited several engines by a number of manufacturers. These included two Mercedes Benz units, one having six cylinders of 95mm bore by 120mm stroke and developing 60/94 b.h.p. at 1500/2600 r.p.m., fitted with fresh water cooling, heat exchanger and an electro-magnetically operated reverse-reduction gearbox. The second engine was a Vee 8 cylinder engine of 165mm bore by 175mm stroke and developing 285/600 b.h.p. at 1000/2200 r.p.m. There was an M.D.6 six-cylinder David Brown engine and the new Mark M.D.2 air-cooled two-cylinder unit by the same makers. This is a direct injection, overhead valve, four-stroke engine, developing 9 h.p. at 1200 r.p.m. and 12 h.p. at 1600 r.p.m. Also shown was the "Delphine" outboard motor with extended drive, which is a combined propelling and steering unit. The water-cooled four-stroke motor has four cylinders of 3in bore by 3½in stroke, a compression ratio of 5·6 to 1 and develops 30 h.p. at 3000 r.p.m. Ignition is by high-tension magneto and the engine is pressure lubricated by a gear pump, while the cooling water is circulated by the kinetic energy of the propeller.

John I. Thornycroft and Co., Ltd., had on its stand a full range of diesel engines manufactured by the company as main propulsion units and for auxiliary power and ranging in power from 12½ b.h.p. to 125 b.h.p. Also shown were examples of Thornycroft propellers and an oil-operated gearbox to transmit a maximum of 325 b.h.p. Another exhibit was a sea-going motor cruiser, which was powered by a Mark R.T.R.4/D1 engine of 30 b.h.p. at 1750 r.p.m., fitted with an oil-operated reverse and 2 to 1 reduction gear and single lever control. The engine gives the boat a speed of 9 knots and the boat, which measures 30ft long by 9ft 3in beam and is of round bilge, was of considerable interest, since it was built at the company's Singapore shipyard and demonstrated the class of construction and workmanship obtainable there.

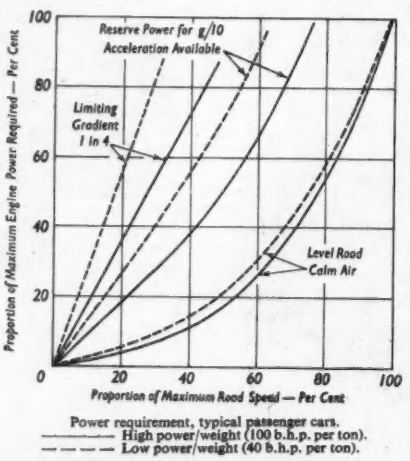
Hydrokinetic Fluid Drives

By J. G. GILES, B.Sc. (Eng.), A.M.I.Mech.E., A.M.I.E.E.

The Automobile Division and Hydraulics Group of the Institution of Mechanical Engineers heard, on January 8, "A Review of Hydrokinetic Fluid Drives and their Possibilities for the British Motor Industry." After an account of the work, largely German and American, done to date, Mr. Giles discussed the extension of such transmissions to less powerful vehicles, as recorded below.

Application to Lower Power/Weight Ratio Vehicles

ECONOMIC conditions in Europe have given rise to passenger cars of lower power/weight ratios than their transatlantic equivalents, so that it will be clear that a greater proportion of the maximum available power will be required at most road speeds, and that a transmission capable of delivering power in a manner similar to the four-ratio stepped transmission would be a suitable solution. On certain more powerful European passenger cars, four-ratio automatic transmissions similar to the "Hydramatic," and fluid converter transmissions aided by three gear ratios, are already available, so that it is useful to consider whether these and other less powerful cars could not usefully adopt some of the simpler versions of automatic transmissions.



Power requirement, typical passenger cars.
———— High power/weight (100 b.h.p. per ton).
— — — — Low power/weight (40 b.h.p. per ton).

Fig. 1—Comparison of the power requirement curves for cars with high and low power/weight ratios at various road speeds

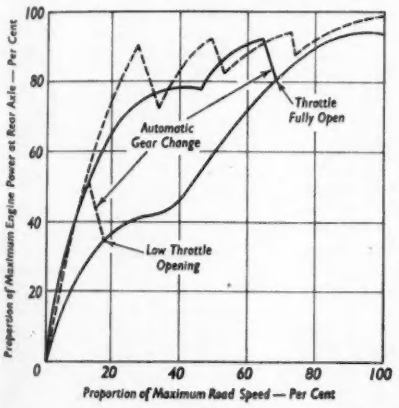
The two-speed fluid converter transmission limits the power available for certain portions of the speed range so that Fig. 1 is useful for comparing the power requirements of cars of high and low power/weight ratio under various road conditions. The car with high power/weight ratio probably has a higher maximum speed, but at all cruising speeds, when referred to as a given proportion of this maximum speed, the power demand of the two cars is seen to be very similar when travelling on a level road. Assuming that for cruising a reserve of power should be available, then this graph shows that a small reserve sufficient to give an acceleration of 1/10 g (or climb 1 in 10 gradient) requires that full engine power should be available at about 60 per cent of maximum speed for the car with lower power/weight ratio. Similarly, considerations of a limiting gradient of 1 in 4 require that a much greater proportion of power is available at all road speeds for the car having a low power/weight ratio as compared with a high power/weight version. Efforts to increase the transmitted power for European cars using the two speed fluid transmission will probably involve the increased use of the auxiliary gear which would be expected to have a ratio of about 1·6 to 1 in order to improve the power reserve in the intermediate range of road speeds. This value of auxiliary ratio will mean the incorporation of a converter having a larger maximum torque ratio in order to start off on the limiting gradient, and will reduce the amount of engine braking available for hill descents so that extra braking provisions or the introduction of fade-free brakes may be necessary.

Increased power could be available by matching the fluid converter at higher engine stall speeds, but this process causes an increase in petrol consumption. A useful idea to increase the engine stall speed whilst in the auxiliary low ratio is to insert this gear between the engine and converter when the stall speed will be raised roughly in the proportion of $R^{3/2}$. The use of a ratio of 1·6 would thus roughly double the

engine stall speed which, if kept down to about 1500 r.p.m. initially, would be valuable in obtaining a useful power envelope, yet maintaining a reasonable fuel consumption. In such an arrangement an automatic gear change between low and high ratios will be controlled by a combination of throttle setting and road speed in the present conventional manner, so as to obtain the best balance of economy and performance.

Fig. 2 compares the transmitted power for such a two-speed fluid converter coupling transmission with the output of a four-speed stepped transmission, and it is seen that only the peaks of the areas representing the three lower gears of the stepped transmission are not covered by the power envelope of this two-speed transmission. The use of the gearing stage between the engine and converter is seen to give a superior performance as compared to other arrangements, and makes the two-speed transmission more attractive for the cars with lower power/weight ratio. It seems possible that this set of reduction gearing could be housed in the torque converter assembly in order to bring about some weight reduction. Other advantages of this arrangement are that the control member will be a sun gear requiring a smaller applied torque, and that the reduced pump speed when the auxiliary gear is engaged could reduce the idling drag torque by about 60 per cent. Disadvantages of this arrangement are that engine braking is only available at rather high road (and turbine) speeds, and an increased fuel consumption when operating at the higher engine stall speed.

The transmission whose performance is illustrated in Fig. 2 appears to be a very effective

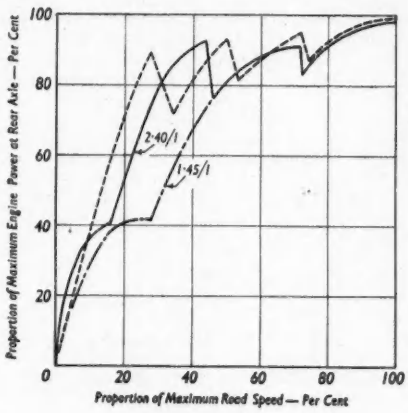


Power envelopes.
——— Fluid converter coupling and auxiliary ratio 1·60 to 1 before converter (high engine stall speed in "low").
– – – – Four-ratio stepped transmission.

Fig. 2—Comparison of the power transmission of a two-ratio fluid transmission having a higher engine-stall speed in low ratio with that of an equivalent four-ratio gearbox

use of a fluid converter aided by one set of epicyclic gearing. Choice of the auxiliary ratio will no doubt be affected by a number of factors, including the shape of the engine power curve and the desire to achieve a given ratio of engine stall speeds in the low and direct drive gears. Some engineers will prefer a lower ratio in order to give a better third gear performance, whereas others may prefer a higher ratio for improved engine braking, but in any case the choice will also depend on the type of vehicle considered.

For certain applications the difficult choice of the auxiliary ratio would lead to the consideration of a three-speed fluid transmission. In view of the fact that many modern motor-cars use a three-ratio gearbox, some engineers would feel that the increased performance obtainable by incorporation of the converter unit is not necessary and that the use of a fluid coupling would be more suitable. For vehicles where performance equal to that given by a four-ratio gearbox is necessary then the use of a fluid converter coupling and a three-speed auxiliary gearbox is required. A convenient way of obtaining the third ratio is to use a "lock-up" clutch, which is utilised for the high ratio (top gear), when the converter coupling is locked in direct drive. A single set of epicyclic gearing is employed to obtain two additional low ratios, so that this version of the fluid transmission is similar in some principles to the Borg-Warner or Ford automatic transmission and requires only a few extra components additional to those required for the two-speed transmission. The performance of this three-speed fluid transmission is shown in Fig. 3, and the use of the lock-up clutch is noticed as the portion of the



Power envelopes.
——— Fluid converter aided by two auxiliary ratios after converter. Converter fitted with lock-up clutch.
– – – – Four-ratio stepped transmission.

Fig. 3—Comparison of a fluid transmission having a lock-up clutch with the power transmission of a four-ratio gearbox

graph where the curves for the fluid transmission and the stepped ratio transmission coincide. This clutch provides a drive of higher efficiency and should result in some saving of fuel when brought into operation.

The foregoing leads to the conclusion that this form of fluid transmission is capable of being applied to cars with lower power/weight ratio when considered on the basis of power transmission. One deficiency of this type of transmission not revealed by considerations of transmitted power is the fact that it is difficult to obtain an overdrive feature. The various forms of overdrive gear now available in Great Britain are proving to be popular, and although the fluid converter transmission has been adopted in the United States in place of the overdrive gear, it does not follow that the same will be true under European conditions. There is considerable evidence of the benefits obtainable by the use of a wide range of transmission ratios, and it may be difficult for the fluid transmission to compete with the increasing use of a wider range of ratios, including the use of multi-ratio gearboxes.

Another difficult feature to overcome is the size and weight of the fluid transmission, since the difference in diameters of a 50 h.p. and 150 h.p. converter is only 8 per cent, so that from experience of the American transmission a 50 h.p. version will be too heavy or too bulky for inclusion on many smaller cars. Production problems are numerous and are accentuated by the lower level of quantities dealt with by European factories. Some of the production techniques may be new to the industry and consist of complex casting or sheet metal fabrication made to high accuracy and requiring attention to surface finish, strength and balancing.

The associated gearing consists of epicyclic or planetary units combined with clutches, freewheels and friction band brakes, which may be operated by a hydraulic system manufactured to fine limits. New machinery or tools will be required to produce some of these items and it is difficult to see how the cost of these transmissions can be reduced to a level low enough to be attractive for the more popular type of car.

Discussion

Mr. A. G. Wilson: The British motor industry is particularly associated with small motor-cars, and it seems that the small motor-car is the Cinderella when it comes to automatic transmission, when, in fact, it is the very vehicle which needs it more than anything else.

Having been associated for some time with automatic and semi-automatic transmissions, I know to my cost that as you go down in size so you do not go down in the cost of the mechanism.

The thought that I would like to put to you is this. Is it not possible for a re-evaluation to be made of the power unit of the small car, particularly from the point of view of automatic transmissions? In other words, if we think of the engine of the small car developing perhaps 40 h.p. or 50 h.p., to make that engine develop perhaps 50 per cent more might add less to the cost of the vehicle than putting a two-speed gear behind a torque converter. Is it not putting the cart before the horse to talk of making intricate automatic transmissions for small cars when, in fact, it would probably be better to spend more money on the power unit and make a very much simpler transmission? If the engineers, instead of taking an accepted engine design and saying "We must put an automatic transmission behind that," would think of the whole thing as a power unit and be prepared to redesign and rethink the engine, they would probably get the result they want with possibly no more cost, and perhaps less cost, by putting much more engine and much less transmission.

Dr. J. K. S. Stuart: A minor point which is well known is the use of the torque converter characteristic, which does not permit the engine to develop high torques at low speeds, to allow some increase in the compression ratio. This effect will to some extent offset efficiency losses in the transmission in normal driving.

My main point relates to the comparison of power availabilities. In comparing performances it is important to remember that all gears in the stepped transmission are not used to the same extent. First gear in a three or four-speed gearbox is presumably chosen to enable the car to be driven away from rest and to be started on the steepest slope which is likely to be encountered. In fact, first gear is rarely used at all on a four-speed gearbox, and it is adequate for a hydrokinetic torque converter to provide sufficient stalled torque to permit starting on such a hill, although torque falls away rapidly with output speed. Incidentally, no comparison has been made between hydrokinetic transmissions and orthodox three-speed transmissions.

As a final comment, I am somewhat alarmed to detect a note of complacency in the discussion. To my mind, the synchromesh stepped gearbox is an anomaly in the modern motor-car, and, pending the development of a transmission which approaches more closely to the ideal, it is too easy to over-emphasise the shortcomings of existing systems, particularly the hydrokinetic system.

Author's reply: Mr. Wilson's remarks regarding the matching of the engine with torque converter are very useful and deserve consideration. To a transmission engineer it seems a failure to have to put a bigger engine in to do the job which he is supposed to be doing—although I would lean to the view of considering engines and transmissions together. To-night, we have seen transmissions exhibited with their efficiency curves. I think it is about time that a few engine designers did the same thing. It would reveal that the engine has parts which are not very efficient and that considerable losses are taking place. If we can combine the characteristics of the two devices in a suitable manner, each of us could make up for the other's faults and improve the overall device, which would at least improve fuel economy. Whether this will be done with the larger engine I am not too sure.

P.V.C. Fume Removal Fans.—Two series of fans are now being made by Keith Blackman, Ltd., Mill Mead Road, London, N.17, in moulded P.V.C. material for handling corrosive fumes. The series No. 1 fans are made with 6in and 12in impellers, and have a fume handling capacity of 50 to 180 cubic feet per minute at pressures up to 1·25in W.G. The series No. 2 fans are made with nine sizes of impellers from 15in to 42in with volume handling capacities up to 40,000 cubic feet per minute against pressures up to 4in W.G. The fans are completely resistant to the corrosive effects of a wide range of alkalis and acids, and have a safe operating temperature up to 120 deg. Fah.

Electric Gear Selection

VEHICLE transmissions have hitherto employed electrical control systems simply as a link between the driver and the gearbox ; an example is the " Preselectric " transmission of Armstrong Siddeley, which uses electric switching to allow an unambiguous selector movement, the gears actually being engaged by the driver's pedal effort. Electric signalling was used by A.E.C. in their " Monocontrol " transmission, described in our issue of October 8, 1954, page 477, and has now been used to provide an automatic transmission control with an unusual degree of sophistication, the "Automonocontrol": it will displace electro-hydraulic selection on London Transport " Routemaster " buses.

The gearbox, seen in Fig. 1, and its valve unit are identical with those of the earlier system, but a new rear bearing housing carries an alternator, from which the speedometer generator is driven in its turn. This alternator is a permanent magnet machine based upon those used on four-stroke motor cycles ; since the load on it is of the magnitude of milliamperes, its life is long and no rise in temperature occurs to alter its characteristics—a close approach to an output linear with speed over the working range is claimed.

The other source of information needed for automatic transmission control is an accelerator switch, provided with four contacts which close at initial, one-third, two-thirds, and complete accelerator pedal travel. These contacts control the current from the vehicle electrical system to the control unit.

Fig. 1—Self-changing gearbox fitted with (left) valve unit and (right) generators for transmission control and speedometer

Some details of the control unit can be distinguished in Fig. 2. Prominent on the right-hand side are a rectifier and two electrolytic condensers, which convert the alternator signal to a smoothed d.c. voltage. The three relays in the foreground each have two windings, one carrying current from the alternator and the other current from the accelerator switch ; the ampere-turns in each are roughly 60 : 40 in proportion, so that random variation in one current does not call for an undue change in the other. The closing of these relays determines the speed at which a change is made between first and second, second and third, or third and fourth respectively. The panel carrying these relays and their associated wirewound resistors is readily removable, so that they can be adjusted in the workshop to give the speeds in each gear best suited to the routes of a particular operator ; in this way the greatest economy can be achieved.

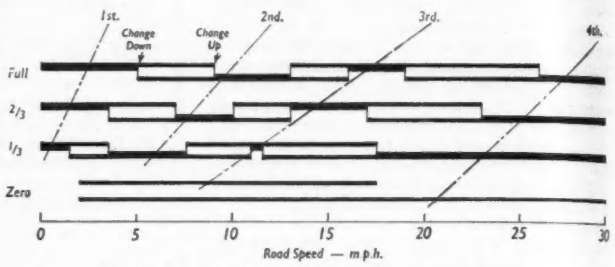


Fig. 3—Influence of accelerator position on gear changes

Beyond the load-speed interpreting relays can be seen a set of four Post Office relays ; the nearer three of these dictate changes by the electro-pneumatic valve unit from one gear to the next. They are not, however, slaved completely to the relays previously discussed. When the accelerator is past its initial opening position, however, and the selector switch is in " Automatic " (replacing " 4 " on the " Monocontrol ") these relays obey the previous set and give the gear changes shown in Fig. 3. It will be noticed that there is a large " hysteresis loop " for each change, militating against the possibility of repeated changes of one relay at the same accelerator position. This characteristic is so marked that, it can be seen, at 12 m.p.h. depression of the accelerator from one-third to full open will take the box from fourth to second ; the third gear valve will in such a case be energised instantly, but the pneumatic system will not have time to take action.

When the accelerator pedal is released, however, a fresh and interesting set of relations obtains. Upward changes can take place—if, for instance, the vehicle is running downhill—but changes down if either fourth or third is engaged are prevented by what is called an inhibitor circuit. Either of these gears may therefore remain engaged until the speed drops to 2 or 3 m.p.h., when neutral is selected ; any other gear automatically selected will also be abandoned below those speeds when the accelerator is up. The effect of the initial movement of the pedal is to cause the control unit to pick up first gear.

Manual selections by means of the selector switch override the control unit completely, and are necessary to obtain effective braking from the engine, with one exception : in order to prevent the vehicle being started from rest on the driving bands, when the vehicle is at rest no selection becomes effective until the accelerator is released.

This neutral-finding facility might be thought to dispense with the need for the fuel-wasting fluid coupling. This, however, is not so, for two reasons : the required life of a gearbox is of the order of 200,000 miles in omnibus service, and the first gear friction linings could not approach this endurance if called upon to act as a clutch—also, the great inertia of the gearbox would unfavourably affect the resonance of the engine at low speeds if directly coupled to it.

This automatic transmission was demonstrated to us by A.E.C. in a slightly different version, preferred for driving in heavy traffic, in which first is never selected automatically, and all changes up from second take place at 15½ m.p.h., regardless of the torque : the latter modification had the result that, at one-third accelerator travel, at 15 m.p.h., either second or fourth, but not third, might be engaged. Possibly because of this, the driver appeared to have some difficulty in anticipating changes : the advantage of this advance from " Monocontrol " lies, of course, not in a smoother ride for the passengers so much as in a less tiring vehicle for the driver and a reduced instructional load on the operator. The neutral-finding function resulted in a usually quiet and smooth idle, which must save fuel. To the passenger, it seemed that if the inhibiting circuit were also to suppress upward changes, it would not only improve the response when baulked and allow less use of the brakes, but also minimise the number of downward changes initiated by increase of fuel rack setting, which were those most noticeable by reason of the marked surge of acceleration.

It is interesting to recall from our account of last year's Commercial Motor Show (October 5, page 471), the controls evolved by Self Changing Gears, Ltd., for the same transmission. These incorporate a direct current road speed detector, excited by the vehicle at battery voltage, and the output of this is applied in opposition to the accelerator signal on the single winding of each relay. On the C.A.V. system the driver has complete authority to engage any gear except fourth, restricted only by a simple mechanical interlock on the selector switch, which makes third the only selection available on leaving " Automatic " : if a gear lower than can be used at the prevailing road speed is selected (e.g. first when running fast downhill) on the S.C.G. control, the box will change down progressively through the intervening gears. In either case complete failure of the electric supply disengages all gears ; with the C.A.V. circuit, failure of the alternator is detected by a slugged relay and neutral selected. The S.C.G. control unit, if the speed input disappears, energises the " hold in " circuit, equivalent to the inhibitor, and remains in whatever ratio is in use.

Fig. 2—Units of automatic transmission control

Gas at Work in Industry

AN exhibition designed to present a representative selection of the many ways in which gas is used in industry has been arranged by the North Thames, the South Eastern, the Eastern and the South Eastern Area Gas Boards, and will open at the Horticultural Hall, London, S.W.1, on Tuesday next, January 22. This exhibition, which will remain open until February 2, is the first of its kind, and by showing the range of equipment now available with typical applications it will give some indication of the importance of gas in the industrial field. In the year ended March 31 last, industrial gas sales totalled over 750 million therms, whilst the latest sales figures available from the Gas Council for the period April–June, 1956, showed an increase of 2·7 per cent over those for 1955.

More than seventy manufacturers will be represented at the exhibition and with the four area boards concerned they have arranged for specialists to be available to advise on industrial gas problems and applications. A large number of the appliances will be shown in operation and there will be models of other equipment too complicated or too large to be exhibited. A central exhibit is being arranged to show more than a hundred industrial products in the manufacture of which gas is used. There will be no individual manufacturers' stands and separate sections of the exhibition are being used to show associated products and equipment.

Gas-fired ovens are used for many purposes and a typical application will be shown in one section where two working installations have been arranged to demonstrate stove enamelling. One of these installations incorporates a radiant heat tunnel made by Parkinson and Cowan Industrial Products, and the other uses convected heat in a camel-back conveyor oven of F. J. Ballard and Co., Ltd. The metal melting equipment will include a reverberating and a bale-out furnace in operation, together with a crucible and a Morgan lip-axis tilting crucible furnaces. An "Edgwick" die casting machine of Alfred Herbert, Ltd., in this section will demonstrate one of the uses of gas-fired metal melting equipment in industry.

A shell moulding machine made by Fairbairn Lawson Combe Barbour, Ltd., Leeds, in operation will show the use of a thermostatically controlled oven. This "Shelmolda Duplus" machine, illustrated in Fig. 1 on this page, is designed to produce from fifty to sixty moulds per hour and uses a 24in by 16in pattern plate. Its sequence of operations is so timed that whilst the shell moulding on one pattern is being cured in the oven, the shell is being removed from a second pattern plate, which is then reinvested. When the second pattern plate is returned to the oven the first one is ready to be taken out. The machine incorporates a handwheel operated pattern plate turnover mechanism, automatic dump box turnover equipment, and pneumatic ejecting gear for removing the shells from the pattern plates.

A section exhibiting high-temperature radiant heating is designed to show the use of radiant heat sources above 700 deg. Fah. The equipment will include an example of the way in which the North Thames Gas Board has used its resources to assist industry by the development of a special annealing plant for collapsible tubes. These tubes are produced on extruding machines at a rate of sixty per minute and they are carried through the annealing chamber of the equipment on an 11½in wide conveyor belt at a proportional speed. The annealing chamber is just under 5ft long by 13in wide, and the height of the radiant surface, which forms its roof, can be adjusted to suit the size of the work. The equipment is designed to operate at 700 deg. Cent. and the conveyor speed is normally set for the containers to attain a temperature of 450 deg. Cent. during their passage through the chamber. The gas supply to the radiant heating burners is governed to a pressure of 2·5in w.g., and the air is supplied to them at 20in w.g. Mounted in the main fabricated angle framework for the heating chamber there is a thick insulating lining of slabs forming the two sides and the base of the chamber. A carrier frame for the burner equipment is supported through screws on the top of the main frame, and through these screws the height of the radiant surface of the roof of the chamber is adjusted with reference to scales.

Another piece of equipment in which an area board co-operated with a manufacturer in the development of a prototype is a combined forge furnace and blowpipe brazing hearth, made by A. H. Wilkes and Co., Ltd., Stourport-on-Severn, Worcs. This equipment includes a pedestal-mounted, 14in by 12in hearth, with a motor-driven blower and two ½in blowpipes. An air hardening unit is also operated from the blower. By the removal of the top and side firebacks the forge furnace is quickly converted to a brazing hearth.

A number of manufacturers will show a variety of equipment for industrial space heating, hot water supplies, and heaters for catering equipment. A group of liquid heating tanks for degreasing and other cleaning processes is designed to show some of the different methods of gas heating which can be used. It will also include two examples of gas-fired steam-raising boilers. The flame processing equipment shown will include examples of profile cutting machines, brazing machines, metal spraying equipment, and a flame hardening unit with automatic control.

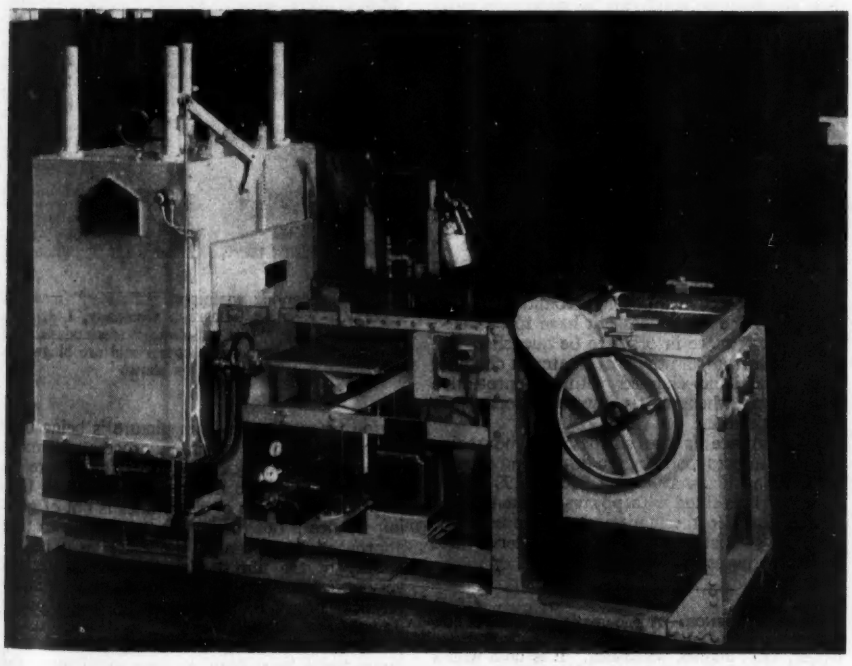


Fig. 1—Semi-automatic shell moulding machine with gas-fired, thermostatically controlled oven. With a capacity of fifty to sixty moulds an hour this machine produces moulds with an effective area of 23in by 15in and a maximum pattern depth of 5in

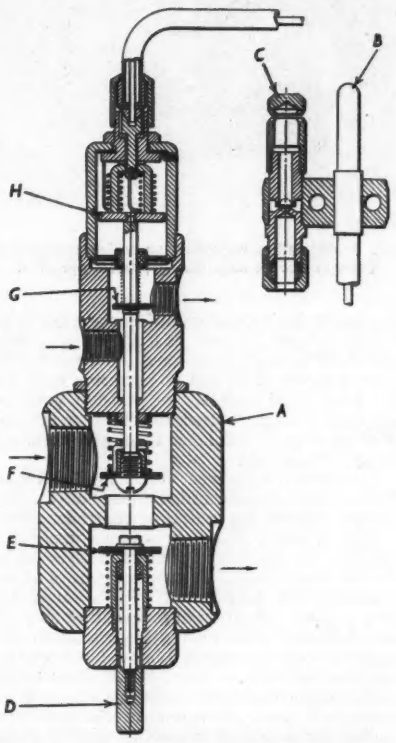


Fig. 2—Arrangement of ignition and combustion protection set with independent pilot control

Industrial gas burners and small appliances of many kinds, as well as instruments and controllers for all purposes, are being shown. One of the many combustion safeguard controls to be shown is the "Junopilot" equipment of Pearl Controls, Ltd., 672, Fulham Road, London, S.W.6, shown diagrammatically in Fig. 2. This equipment controls the pilot gas supply as well as the main gas supply in the event of flame failure. In it the current operating the electromagnetic safety valve *A* is generated when the tip of a thermocouple *B* is heated by the flame from a pilot burner *C*. In operation when the push button *D* is pressed up a plate *E* is brought on to its seating, preventing flow of main gas, and valve *F* and pilot valve *G* are lifted into the open position. Gas is then free to pass to the pilot burner and on heating of the thermocouple tip both valves are held open by the attraction of armature *H* to the electromagnet above. Release of a push button allows gas to pass to the main burner, or releases a weep gas flow from the relay valve as applicable. On failure of the pilot flame, valves *F* and *G* drop on to their seatings, shutting off both pilot gas and main gas supply. The chamber in the pilot body is separate from the chamber in the main body, and pressure can be maintained in the pilot body during periods when pressure in the main body is low, e.g. under thermostatic control.

A bridging ladder burner made by the same firm consists of a tube which has a continuous slot along one side and has a central tube provided with a number of small orifices. Gas issuing from these orifices enters the annular space between the two tubes and flows through the outer tube slot to provide an evenly burning flame. The substantial width of the slot

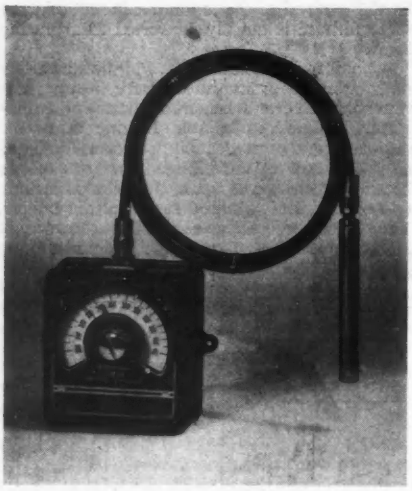


Fig. 3—Indicating controller on which temperature changes can be seen during process operation

practically eliminates chance of blockage and as the burner operates on neat gas it can be used under very dusty working conditions. As the gas burns along the outer tube slot no corrosion occurs in the inner tube orifices. A pressure governor supplied with the burner maintains a pressure of 0·5in w.g. in the inner tube, and ensures a constant flame size.

The control equipment made by Teddington Industrial Equipment, Ltd., Sunbury-on-Thames, Middx, includes the indicating controller shown in Fig. 3, designed for applications where it is necessary to observe temperature changes during a controlled process. It provides control at any predetermined temperature over a range and gives a visual indication of temperature throughout the entire cycle on the same scale as that used for control setting. In it a temperature sensitive bulb is connected by capillary tubing to a flexible metallic bellows assembly in the instrument case. Temperature changes cause the bellows to expand or contract and this movement is used to raise or lower a lever which operates a striking arm to trip the switch when a preselected temperature is reached.

The position of the striking arm in relation to the lever is set by a cam rotated by an adjustment knob to determine the temperature at which the switch will trip. Movement of the lever is also transmitted to a quadrant and pinion to move the indicating pointer across the dial, thus providing an independent registration of process temperature.

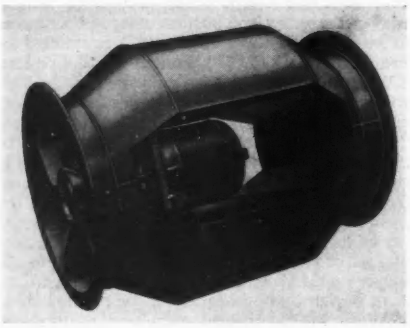


Fig. 4—Hot fume extraction fan with bifurcated housing

In addition to a selection of the burners and controllers made by Keith Blackman, Ltd., this firm will exhibit a fan specially developed at the request of an area gas board for handling the products of combustion from small gas furnaces. This equipment, as can be seen from Fig. 4, consists of a 10in diameter fan arranged in a bifurcated housing in such a way that corrosive fumes and the hot products of combustion do not pass over the fan motor. This firm has also loaned a motor-driven gas booster, which is being used to provide gas for all the equipment demonstrated in operation in the exhibition. This booster is designed to handle some 8000 cubic feet of gas an hour.

In a representative group of gas-fired furnaces for the heat-treatment of metals is a standard, double-ended section heating furnace of Thermic Equipment and Engineering, Ltd., of Preston. These furnaces, one of which is shown in Fig. 5, are built for the heating of steel sections, and they can be supplied in accordance with the length of work it is required to heat and the work section. In each furnace the gas burners on each side have their ports arranged at a converging angle to suit the section being heated. The length of work heated can be set from about 4in to the maximum length of the furnace by regulating the number of burners in operation.

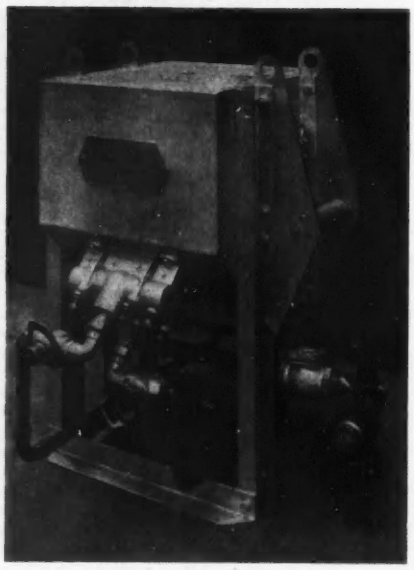


Fig. 5—Double-sided gas-fired furnace for heating long sections

Thus work up to the length of the furnace can be heated overall or in part, whilst work longer than the furnace itself can be heated in parts whilst the outer ends project through the doors at each end.

Birlec, Ltd., of Birmingham, will exhibit the largest single piece of gas-fired equpment to be shown at the exhibition. It is a newly developed sealed quench furnace with its ancillary endothermic gas plant for generating a protective atmosphere, and it is designed for carbonitriding, gas carburising, bright hardening, clean normalising and carbon restoration. To some extent a development from the previous "Birlec Dow" designs, the furnace represents a departure in heat-treatment practice since it makes provision for direct quenching of the work whilst preserving intact the protective atmosphere round the heated material. The work does not have to be taken out of the furnace in order to be quenched, but it is withdrawn from the heat-treatment chamber into a vestibule charged with the protective atmosphere, whence it is lowered directly into the quench tank.

This furnace is the smallest of the sealed quench furnaces made by the firm, being capable of handling loads averaging 200 lb, 650 lb and 1400 lb. It is fitted with power-operated doors, charge transfer mechanism, and process time controls, so that one man can easily serve three or four furnaces.

DIESEL GOVERNOR.—A pneumatic governor is now available on the "A" size jerk pump made by Bryce Berger, Ltd., Staines, Middlesex. It is used with a venturi including a throttle butterfly on the induction manifold, and acts as an all-speed governor. The idling stop is spring-loaded, so that injection ceases completely when the engine is being used as a brake.

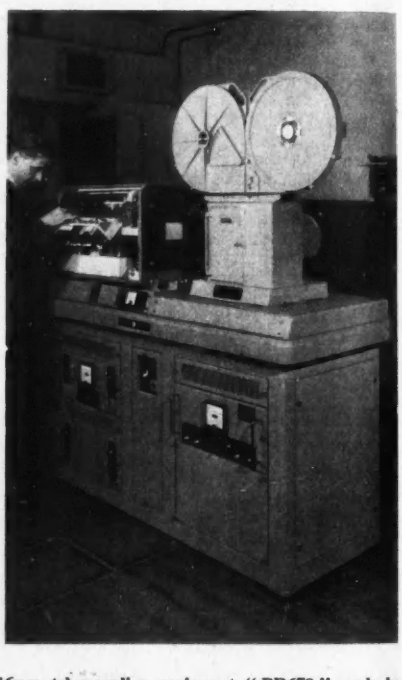
16mm Telerecording Equipment With Fast Pull-Down Mechanism

WE illustrate a new 16mm television recording equipment "BD679," produced by Marconi's Wireless Telegraph Company, Ltd., Chelmsford, Essex. One such equipment is in service with the British Broadcasting Corporation and another has just been commissioned by the Bayerischer Rundfunk, in Germany.

The process of making a film record of a television programme for subsequent retransmission is achieved, basically, by feeding the video signals and synchronising pulses to a cathode-ray tube capable of producing an intensely bright, short-persistence picture. This picture is optically focused on to a "frame" of negative film stock and thereby photographed, the film then being moved on one "frame" for the taking of the next picture, and so on. The reel of the film is then developed and processed in the normal way for future use.

Although the process is theoretically straightforward, its practical realisation poses many problems. For instance, in order to record full picture information, the film must be stationary in the gate for the period of the two scanning fields which make up one complete television frame or picture; this means that the only time left in which it can be moved on for the next exposure is in the brief blanking period between television frames.

Because this blanking period varies between 1·4 and 1·8 milliseconds, two opposing requirements have to be reconciled. First, ideally the film must be pulled down into position in this very short time, as any overlap into the period when the television picture is being built up by the normal scanning process will mean that some of the scanning lines (and therefore picture-content) are not registered on the film. In practice, the loss of a few lines is not of great importance; but the nearer the pull-down time approaches these limits the better will be the quality of the filmed picture. Secondly, it is very important that the film itself must not suffer physical injury in the process of being pulled down.



16mm telerecording equipment "BD679" made by Marconi's Wireless Telegraph Company, Ltd. The equipment has a "fast pull-down" mechanism. The sub-chassis have removable covers and are hinged for servicing as shown

On conventionally interrupted cameras pull-down times have been so long as to make the arrangement quite unworkable for telerecording, and hitherto the usual practice has been to record only alternate television frames, the others being

blanked out and the intervals used as "breathing spaces" in which the film is pulled down.

The Marconi telerecording equipment "BD679" incorporates a new and fast pull-down mechanism which operates in the normal time of 2 milliseconds, but which can be adjusted to give a pull-down actually within the blanking period. A very light gate pressure is employed, while positive registration of the film is achieved against a sapphire-tipped claw. The fast pull-down mechanism itself is totally enclosed in an oil bath and can be quickly removed as a sub-unit. A very simple optical system is incorporated which ensures that there is negligible loss of contrast in the recording due to scatter. Magazines of 2250ft capacity (or 2000ft magnetic strip) identical for feed and take-up, are supplied with the camera. "Minutes left" indicators are provided, together with "lost loop" and "take-up-failure" cut-outs. The gate is designed to deal with long recording sessions without attention, and splices can be passed without difficulty. A footage indicator is incorporated in the camera.

The recording monitor, the function of which is to generate (from the externally supplied video signals) an intense high-quality picture for focusing on to the film, is mounted on a swivel head, and may be swung through 90 deg. to facilitate removal of the recorder cathode-ray tube. Because of the flexible design of this unit, any magnetically focused tube of a diameter between 5in and 10in can be used.

A flywheel synchronising panel can be supplied as an optional extra for the regeneration of line and field pulses when the recording is made from a remote location. Other optional extras are a "grey scale" generator, a waveform monitor and a 14in picture monitor.

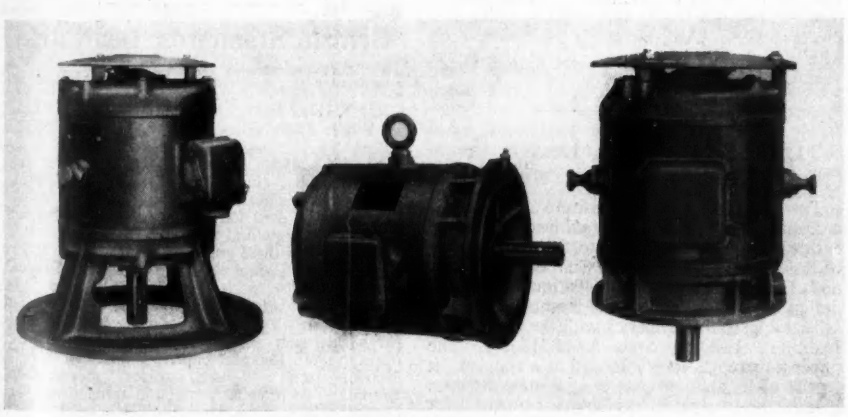
Improved Range of Standard A.C. Motors

A NEW range of standard, ventilated, three-phase, squirrel-cage motors has been introduced by Crompton Parkinson, Ltd., Crompton House, Aldwych, London, W.C.2, in conformity with the Draft B.S. CW(ELE) 6246. This range of motors is known as the "CP Series 5" and it covers ratings from 1 h.p., four-pole, to 50 h.p., two-pole. Examples are illustrated below.

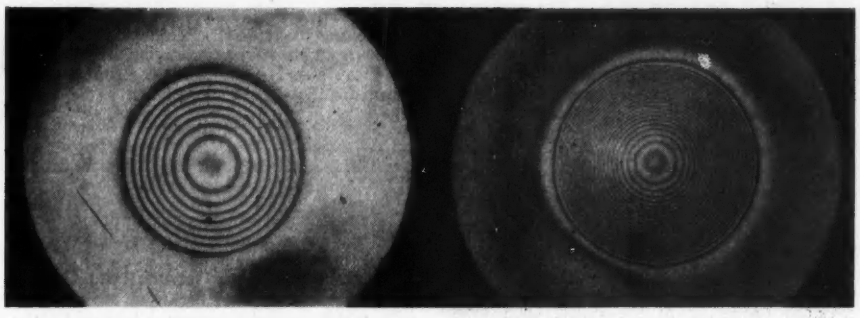
By using Class E insulation, which allows for a temperature rise of 65 deg. Cent., and by adopting an improved cooling system, the manufacturer has been able to reduce considerably the size of a motor for a given rating, as tabulated above. The "Series 5" machines are stated to be up to 40 per cent lighter than the machines they supersede. Cooling air is drawn through the lower part of both end-shields, is directed by baffles over the bearings, then axially towards the centre of the machine, and is then forced radially outwards over the end turns and, finally, axially between the core and the shell before being expelled through central openings in the sides and the base of the machine. Although the motors may now operate at temperature rises of 65 deg. Cent. above ambient, the outer shells will be considerably cooler and the bearings will be no hotter than on earlier motors designed for temperature rises not exceeding 55 deg. Cent. The circulating fan at each end of the machine is an integral part of the rotor and the baffles over the end turns serve as protective shrouds. The stators and end shields are of cast iron and the stators are wound with synthetic enamel-covered wires, the slots being lined with leatheroid covered with polyester film. Die cast rotors are being used for the smaller machines and will eventually be used for the larger sizes in the range. Unified screw threads are standard for all the motors. The main dimensions are the same as those specified for equivalent N.E.M.A. frames, except that the shafts of the new machines are of slightly larger diameter to suit the larger outputs, which are developed in the same frame sizes.

Comparative Dimensions of Old and New Crompton Parkinson 3 h.p Four-Pole Motors with Foot Mounting

	Old range	"Series 5" range
Length over bearings ...	12½in	11in
Overall height	11¼in	8 $\frac{29}{32}$in



Some examples of the new Crompton Parkinson "Series 5" motors. The range also includes horizontal shaft foot-mounted machines



Optical interference patterns of (left) a carbide grade of known chipping tendencies and (right) a carbide grade possessing a higher degree of toughness

Steel-Cutting Carbide Tools

AFTER a detailed investigation into the requirements of industry and development work extending over a period of some three years, Wickman, Ltd., announces the introduction of new grades of "Wimet" steel cutting tools. Two new grades, known as "XL 12" and "XL 13," have already been introduced to replace the former "XX," "XX7" and "X8" grades, and three further new grades will be added to the range in May next.

In announcing the new grades of carbide tools, the firm states that these changes follow examinations and tests which began with an industrial survey in this country in 1953, when technical opinions were sought from a number of individuals and organisations forming as near as possible a cross section of the metal-working industries. The results when summarised clearly showed that the wide range of steels in use, together with the continued development in machine tool design, created new conditions which could be met more effectively by a range of carbide tool grades with extended wear and shock resisting properties, which could be achieved by an increased measure of toughness. In addition to improved performance of such new grades for general finishing and roughing operations, additional toughness would also offer other advantages in that the incidence of cracking during brazing and grinding would be reduced and there would also be less risk of edge snipping and cracking during service.

One of the major problems which had to be solved in development was the establishment of a method of measuring toughness, since it had become increasingly clear that transverse rupture strength was of little significance in relation to the performance of cutting tools in practice. Whilst no measure of permanent deformation occurs in a tensile or transverse rupture test, it is possible to deform carbide locally to a considerable extent before cracking occurs. For example, indentation can be made in the toughest carbide grades with a Vickers pyramid diamond without any visible cracking, but which on closer examination show very small cracks at the corners of the impression.

An attempt to use this method of observing cracking from the corners of the diamond impressions as a measure of toughness was made, but was not successful because of inconsistent readings, probably because of the high concentration of stress at the corners of the impression. As a result, an entirely new approach was made using a spherical indenter applied to a flat, polished surface at increasing loads, until a point was reached when cracking occurred at the periphery of the indentation. Measurement made by optical interferometry provides a relationship between load and depth of impression, up to a point where the carbide begins to crack. A carbide hemisphere proved to be the most suitable form of indenter, and although it is flattened to some extent during the test, it is possible to classify carbide grades in terms of toughness according to the maximum depth of impression which can be made without cracking.

The photographs reproduced above show the optical interference patterns of indentations of maximum size which can be made in two different carbides of varying toughness. The number of interference rings is a direct measure of the depth of the impression. The left-hand illustration shows nine rings and that on the right twenty-three rings, and a number of rings can, therefore, be used as a measure of the toughness of the carbide. It is understood, of course, that the number is constant for reference purposes only if the radius and hardness are also held constant. Both the grades of carbide illustrated had a transverse rupture strength of 230,000 lb per square inch, but the one with the toughness reading of 9 is a grade which was known to be more susceptible to chipping in application than the one with the toughness reading of 23.

Having established a method of measuring toughness, several distinct approaches were then made to the problem of providing the desired physical properties. They included modification to basic materials, carefully manipulated changes in chemical composition, and the employment of additional elements to those normally used in the manufactureof "Wimet." Then there followed a series of laboratory tests to determine

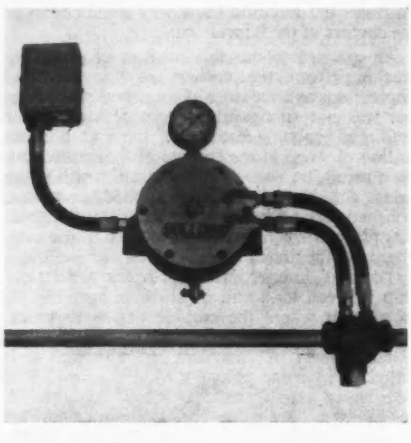
the best combination, and by a process of elimination based on machining tests in the laboratory, a number of grades were selected to provide a later choice based on field tests under more rigorous production conditions. These field tests were carried out on an extensive scale, taking as a basis the widest cross section of different operational conditions and materials it was possible to find, and in direct comparison with the performance of the firm's existing grades of carbide.

The new series of carbides for tools developed by the firm as a result of this work is stated to have high wear-resistant properties at one end of the scale and considerably greater shock-resistant properties at the other, each grade having its own extension of toughness and spaced evenly at intervals between the extremes of the range, allowing a choice of carbide to meet different industrial requirements.

Spray Booth Exhaust Fan Control Device

To reduce the heat losses involved in exhausting warmed air from a paint shop by spray booth fans an automatic fan control device has been introduced by Alfred Bullows and Sons, Ltd., Long Street, Walsall. This device automatically switches off a spray booth exhaust fan when the spray gun is no longer in use, and switches the fan on again as spraying restarts. By only exhausting air whilst spraying is in progress unnecessary heat loss is avoided and the power consumption of the exhaust fan motor is reduced.

The firm points out that time study in many spray booth installations has shown that an operator actually only uses his spray gun for about one-third of a working day, the rest of his time being spent in handling material and preparation of work and equipment. In most installations the exhaust fan is running all the time, so



Device for automatically starting and stopping spray booth exhaust fan as spray gun is operated

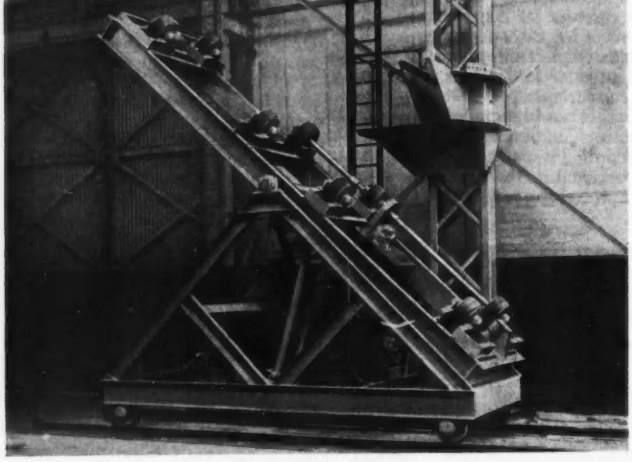
that it may be possible to save up to two-thirds of the existing heat loss.

The device can be seen in the illustration and is of very simple construction. A slight local restriction is fitted in the main air line feed to the spray guns on the booth. The air flow caused by the spraying operation induces a slight pressure drop on the downstream side of the restriction, and the variation in pressure on either side of this is used to actuate a diaphragm cylinder. This diaphragm controls an air feed valve to a small reservoir, and in turn a pressure switch which completes the circuit for the fan motor.

A permanent bleed to atmosphere takes place from the reservoir, so that when spraying stops the pressure in the reservoir gradually decreases until the pressure switch breaks contact. The rate of bleed is adjustable, and a variable time lag is produced before the fan motor stops. Normal setting is for a delay of 1½ to 2 minutes after spraying ceases, and this prevents the fan cutting in and out repeatedly if the operator triggers at the end of each stroke, or otherwise stops spraying for short periods, such as to change position or to clear a gun stoppage. It also ensures the removal of overspray which may remain in the booth after spraying ceases. When the spray gun is used again the fan starts up automatically within two seconds.

Tilting Turning Rolls for Welding Cylindrical Work

THE tilting and turning roll equipment combined with a welding head manipulator shown in the illustration has been built by Donald Ross and Partners, Ltd., Gatwick Road, Crawley, Sussex. As can be seen, the frame of the turning rolls, which are rated to carry a load of 10 tons, is pivotally mounted at the centre on an apex frame of a rail carriage. The roll frame can be tilted up to 45 deg. either way by means of hydraulic rams. The three rolls on one side of the bed are power-driven to rotate cylindrical work, and a set of idler rolls at one end of the



Tilting turning rolls for welding cylindrical work: the roll frame is here tilted at 45 deg. At its rear there is an automatic welding head manipulator fitted with a boom

bed is adjustable longitudinally along the frame in accordance with the length of the work. When the frame is tilted the work is supported by end thrust rollers set centrally in the end cross-members of the frame.

This design of equipment can be used for longitudinal and circumferential welding, and the facility of tilting in each direction also enables fillet welding of such things as stiffening rings, and circumferential fittings.

The automatic welding head manipulator shown in the illustration is designed to carry the head on an adjustable boom. This boom is raised and lowered by a power winch and operates at all heights from 3ft to 16ft above floor level. The main column is mounted on the floor and on it the boom is rigidly supported by guide and thrust rollers. An operator's platform fitted with guard rails is incorporated in the boom structure.

Ultimate Strength Design in Reinforced Concrete

THE American Concrete Institute has reprinted a report published in its *Journal* last November, entitled "Guide for Ultimate Strength Design of Reinforced Concrete," by Charles S. Whitney and Edward Cohen. The ultimate strength design of reinforced concrete members received official approval in America with the issue of the Institute's building code A.C.I.318–56. The paper now reprinted is intended as a supplement to the code, and presents the ultimate strength method of design in its simplest form, with working equations and design charts. Problems not covered by the code, such as shear, bond and deflections, are treated on the basis of the authors' experience. Design problems dealt with include: rectangular beams, or slabs with or without compression reinforcement; "T"-beams; concentrically loaded short columns; combined bending and axial compressive or tensile loads; slender compression members; shear and bond, and deflections. A set of fifteen design charts gives curves of essential data for the problems. The paper and sets of 12in by 12in enlargements of the charts are available from the American Concrete Institute, P.O. Box 4754, Redford Station, Detroit 19, Michigan, U.S.A.

International Conference on Soil Mechanics

THE fourth International Conference on Soil Mechanics is to be held in London, at the Institution of Civil Engineers, next August. Details of the programme of events—which include the social functions and post-congress tours generally associated with international meetings of this kind—have recently been announced. Previous conferences organised by the International Society of Soil Mechanics and Foundation Engineering have been at Cambridge, Mass, in 1936, Rotterdam in 1948, and Zurich in 1953. The technical sessions of the fourth conference will be divided as follows: soil properties and their measurement (reporter I. Th. Rosenqvist); techniques of field measurement and sampling (reporter Milton Vargas); foundations of structures—general subjects and foundations other than piled foundations (reporter J. Brinch Hansen); foundations of structures—piling and piled foundations (reporter Philip C. Rutledge); roads, runways and rail tracks (reporter R. Peltier); earth pressures on structures and tunnels (reporter J. Kerisel); earth dams, slopes, and open excavations (reporter Fred C. Walker). The conference publication committee received more than twice the number of papers which could be printed, and so a quota was allocated to each national committee, and papers have been edited. The chairman of the organising committee of the fourth congress is Dr. W. H. Glanville, and the secretary Mr. Banister. Persons not belonging to the international society may attend the congress; further details can be obtained from the congress secretary at the Institution of Civil Engineers.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

OIL-HARDENED AND TEMPERED STEEL WIRE FOR GENERAL ENGINEERING PURPOSES

No. 2803 : 1956. Price 3s. This new Standard, like B.S. 1408, "Hard-Drawn Steel Wire for Springs for General Engineering Purposes," provides for wire which can be used for spring making without subsequent hardening and tempering.

It deals with three grades of wire: Grade 1, high duty (ground); Grade 2, high duty, and Grade 3, commercial.

The standard deals with wire of ½in to 0·036in, diameter, for which the tensile ranges are 80/90 tons per square inch and 115/130 tons per square inch respectively. Requirements are specified for the following tests:—Tensile, torsion, reverse bend, wrapping, deep etch, decarburisation, dead wire. Section 1 of the standard specifies general requirements, and Section 2 contains specific requirements for each of the three grades of wire. Tolerances on diameter and circularity are also specified.

Industrial and Labour Notes

Wage Claims

Last week, there were two meetings at which the engineering wages claim was discussed. The first of them, on Tuesday, January 8, was a meeting of the Amalgamated Engineering Union's national committee, at which the employers' rejection of a claim for a 10 per cent wage increase was considered. Against the advice of the union executive, a proposal was carried in favour of a two-day strike of shipbuilding and engineering workers before the end of February, if "satisfaction" could not be obtained at a further meeting with the employers.

The A.E.U. is a powerful constituent of the Confederation of Shipbuilding and Engineering Unions, but the responsibility for the union side of wage negotiations rests with the Confederation as a whole. The Confederation met on Thursday of last week. A resolution which was passed there made no specific reference to the strike threat. It directed the executive council of the Confederation to seek another meeting immediately with the engineering and shipbuilding employers, and authorised it to say that if there was no satisfactory conclusion, action would be taken to reinforce the claim.

Other recent announcements about wage claims include the acceptance of an offer made by London Transport of increases of 7s. 6d. a week for bus drivers and conductors and of 7s. 4d. a week for maintenance staff. A claim for an increase of £1 a week had originally been made by the Transport and General Workers' Union. It was also stated last week that the Associated Society of Locomotive Engineers and Firemen had decided to accept the wage increase of 3 per cent for drivers and firemen employed on British Railways, which was recommended recently by an arbitration tribunal. At the same time, a delegate conference of the A.S.L.E.F., which made this decision, authorised the formulation of a further claim at any time the executive thought fit. Finally, before the end of the week, the executive of the National Union of Mineworkers stated that it intended to submit to the National Coal Board a claim for an increase of 19s. 6d. a week in the wages of day men.

Employment and Unemployment

At the end of last November, the number of people in civil employment in Great Britain was 23,052,000 (15,239,000 men and 7,813,000 women). This was 11,000 fewer than at the end of October. The Ministry of Labour says that the decline was in many respects a seasonal one, occurring mainly in employment in agriculture, the building trade, and in such miscellaneous services as hotels and catering.

In the manufacturing industries, the number of people at work at the end of November was 9,262,000, which indicated a decrease of 3000 during the month. In vehicle building, there was a drop of 3000 during November in the number employed, the total at the end of the month being 1,217,000, compared with 1,254,000 a year earlier. On the other hand, in the engineering, metal goods and precision instruments group, the number employed increased by 4000 to a total of 2,808,000, which was, however, 17,000 below the figure returned a year earlier.

The Ministry of Labour records in a report on the situation that, in the four weeks ended December 12 last, the employment exchanges filled 127,000 vacancies, the number of vacancies notified to the exchanges but unfilled on December 12 being 279,000. This was 21,000 less than a month earlier and 103,000 less than in November, 1955. It is also stated that, in the week ended November 24 last, there were 1,600,000 workers on overtime in manufacturing establishments, the average being eight hours extra. The number was 230,000 more than at the end of August, but 210,000 less than in November, 1955. In the same week—that ended November 24 last—there were about 73,000 operatives in manufacturing establishments who were on short time, each losing nine hours on the average. This was 39,000 less than in August but 39,000 more than in November, 1955. The number of unemployed in Great Britain on December 10 last was returned as 296,947, or about 1·4 per cent of the total number of employees. The figure was 32,369 above that returned on November 12. It included 106,271 who had been out of work for more than eight weeks, and 29,233 who were described as temporarily stopped.

Overseas Trade

Provisional figures issued by the Board of Trade put the value of exports of United Kingdom goods in December at £253,700,000. This was £40,000,000 below the average for October and November, but the December period contained only twenty-four working days, compared with twenty-six and twenty-eight, respectively, in the two preceding months. Imports in December were valued at £307,800,000, the second lowest figure last year, and £29,000,000 below the average for October and November. But in the early part of December imports were again reduced by the delay in the arrival of ships which had to be diverted round the Cape. Re-exports in December were valued at £11,200,000. The excess of imports over total exports was £42,900,000 in December, which was £5,000,000 below the monthly average for January-November, 1956.

For the whole of last year, the Board of Trade gives a figure of £3173 million as the provisional value of the United Kingdom's exports. This was more than 9 per cent above the record total reached in 1955. Allowing for the inclusion in the 1956 figures of silver bullion repayments to the U.S.A., and in the 1955 figures of shipments delayed by dock strikes, the underlying increase in the value of exports last year was close on 10 per cent. The increase in volume was 6 per cent, and the Board of Trade says that export prices increased by about 4 per cent. The total value of last year's imports is estimated provisionally as £3890 million, which is much the same as the 1955 figure. Import prices were 2 per cent higher than in 1955, but the volume of arrivals was a little lower. The value of re-exports last year was £146,000,000, an increase of 23 per cent over 1955. Assessed on these provisional figures, the visible trade deficit last year was £571 million, which was £288 million lower than in 1955.

Basic Materials Prices

According to statistics collected by the Board of Trade, there was a further rise, of about 1·1 per cent, in the basic materials price index between November and December last. At the end of December the index of basic materials (excluding fuel) used in "non-food" manufacturing industry (June 30, 1949=100) was 161·1. Among the few commodities which fell in price between November and December were copper, tin ingots and lead.

The Board of Trade says that the price index numbers for materials used in the mechanical engineering and electrical machinery industries rose by 1·3 and 0·6 per cent, respectively, in December, the numbers being 181 and 187·8. The increase in both indices was due primarily to higher prices for iron and steel items, brass ingots and rubber, though these increases were offset to some extent by decreases in the prices of some non-ferrous items, including copper sheet, brass strip or sheet, and brass tubes. The price indices for building and civil engineering and house building materials both rose in December by 0·8 per cent. Furthermore, there was an increase of 1·9 per cent in the price index for fuel used in manufacturing industry.

For all manufactured products, the Board of Trade says, the price index continued its upward movement in December with an increase of 0·4 per cent. Among the indices for selected sectors of industry, the most significant increases were those of 2·5 and 2·9 per cent in the indices for iron and steel, and products of the blast-furnace and steel melting and rolling industry. These resulted from the average increase of 6 per cent in the prices of most iron and steel items which became effective on December 17. The index for chemical and allied products rose by 0·9 per cent, mainly on account of higher prices for pure benzole.

Manufacturers' Advisory Service

The National Union of Manufacturers has established a non-profit-making company, entitled National Union of Manufacturers' Advisory Service, Ltd., in order to extend the industrial advice service which it started over three years ago. This service was instituted in 1953 with the help of Counterpart Funds, and has been devoted principally to supplying advice on work study and kindred matters to smaller firms. In announcing the extension of the service, the National Union of Manufacturers has emphasised the fact that 75 per cent of the manufacturing firms in Great Britain have fewer than 100 employees each, but that these concerns alone account for nearly 25 per cent of the country's total production. The staff of N.U.M.A.S., as the new company is known, will continue the work of the advisory service by providing work study officers and cost accountants to help in the carrying out of agreed improvement schemes. Industrial advisers are ready to visit any firm, irrespective of size, to discuss and report on such matters as organisation structure, finance, marketing and distribution, management accountancy, materials control and production. Mr. G. L. Page is the managing director of N.U.M.A.S., the offices of which are at 45–46, St. Paul's Churchyard, London, E.C.4.

Selling Overseas

This week the annual statements made by the chairmen of the Banks have begun to appear. As is customary, they make an appraisal of the economic situation, and comment on various matters closely related to it. One of the statements is that of Sir Harold Bibby, chairman of Martins Bank, Ltd., who makes reference, among other matters, to this country's export tasks. He says that when many manufacturers could sell the bulk of their output in the home market for prompt cash, the incentive to sell abroad under fiercer competitive conditions was small. This is especially so, Sir Harold Bibby suggests, when foreign customers demand deferred credit and the exporter has to comply with a host of clerical obstructions relating to licences, customs formalities and so forth.

The statement goes on to say that the whole emphasis should be to encourage manufacturers to sell abroad rather than at home; one of the most useful contributions to this object, in Sir Harold's opinion, being a drastic simplification and, when possible, abolition of the formalities at present inherent in carrying through the simplest shipment abroad. The era of easy, and often too easy, profits, Sir Harold's statement continues, is rapidly passing, and this, he urges, should call for higher efficiency and determined effort. Many firms, the statement adds, have courageously pegged their selling prices for many months ahead. Provided prices in other directions can be held in check, these firms should reap their reward not only in adding a spur to their own efficiency but also in making a major contribution in halting inflation.

The statement then passes to the comment that restrictive practices, whether exercised by workmen or by employers, are suicidal to both. The worker, Sir Harold says, who denies the most economic use of the latest machinery is, in the long run, and not a very long run, certainly working himself out of the very job that he imagines he is thereby retaining. Equally, the employer who refuses to re-equip his works will soon find himself out of business, being unable to measure up to his more venturesome competitors. Further, the statement observes, in a time of full employment, employers bidding against each other, in the belief that the additional cost can be passed on to their customers, is all too tempting. So is the practice in times of temporary transition of keeping men not fully employed or on short time when they could and should be fully employed elsewhere.

Future Demand for Oil in Western Europe

*The period after the war has been characterised by an expanding demand for petroleum products as well as by the rise of the Middle East as a major area of crude oil production. Increase in consumption as well as the need to conserve foreign exchange, have led to the development of a European refinery industry. The existing position and future outlook as presented before the Suez crisis, are reviewed by the O.E.E.C. oil committee in a report published recently.**

THE consumption of oil in the O.E.E.C. countries has risen from 37,000,000 tons (including 4,000,000 tons of bunkers) in 1947, to nearly 100 million tons (including 13,000,000 tons of bunkers) in 1955, representing an overall cumulative rate of increase of 13·2 per cent per annum. The contribution of petroleum products to the total energy requirements, however, remains below that for the world as a whole, being 11 per cent in 1949 (world=30 per cent) and 18 per cent in 1955 (world=37 per cent). The upward trend in post-war oil consumption has been steeper and more persistent than that of total industrial production, as shown in Table I. In 1949–1951, and 1954–1955, annual

TABLE I—*Development of O.E.E.C. Oil Consumption, Total Energy Consumption and Industrial Production*

Year	Total oil consumption (million metric tons)	Per cent increase over previous year	Index figures at end of year (mid-1948=100)		
			Oil	Total energy	Industry
1947... ...	37·1	—	—	—	—
1948... ...	39·9	7·5	109	103	107
1949... ...	46·8	17·3	128	108	120
1950... ...	55·0	17·5	152	117	130
1951... ...	65·8	19·6	168	125	137
1952... ...	69·6	5·8	183	125	141
1953... ...	75·0	7·8	204	127	151
1954... ...	86·8	15·7	233	135	167
1955... ...	99·9	15·1	270*	144*	180*

* Extrapolated.

consumption increased at rates between 15·1 and 19·6 per cent, the levelling-off in 1952–53 being due principally to a reduction in fuel oil due to a decrease in industrial activity.

The changing pattern of consumption is illustrated by Table II, from which it will be

TABLE II—*Percentage Consumption of Different Petroleum Products*, 1948–1955

		Mean annual compound rate
Motor gasoline	100 ...	10·5
Kerosene	35 ...	4·2
Gas/diesel oil	138 ...	14·0
Fuel oil	210 ...	17·8

seen that while the consumption of motor fuels more than doubled between 1948 and 1955, that of fuel oils more than trebled.

Since the war, many new applications have been developed, such as domestic and commercial heating and electricity generation. In some cases the loss of a traditional market has been more than balanced by the rise of a new one, as in the case of kerosene. Expanded rural electrification and greater use of diesel engine tractors have restricted the kerosene consumption for lighting and automotive purposes, but propeller turbine and jet aircraft as well as domestic space heating have more than made up for the loss.

A substantial increase took place in bunker requirements, which rose from 4·2 million tons in 1948 to 13·3 million tons in 1955. This was due not only to the increase in general maritime traffic, including tanker traffic, which at present accounts for about half the total, but also the trend towards oil fuel in place of coal.

It is of interest to note the consumption per head of population in the various O.E.E.C. countries, as shown in Table III.

A very striking post-war development is the rise of the European refining industry. In 1948, crude oil throughput in the refineries of the O.E.E.C. area was 19·5 million tons, but in 1955, due to expansion, this figure had risen to 103 million tons. With a current capacity of about 120 million tons, the refineries represent

TABLE III—*Inland Consumption, per Head, of Oil Products and Total Energy*

	Oil (kg)		Increase, per cent	Total energy (coal equivalent in kg.)		Increase, per cent
	1948	1955		1948	1955	
Iceland ...	723	1127	56	2190	3000	37
Sweden ...	431	1113	158	2470	3770	53
Norway ...	373	711	91	2690	4200	56
Denmark ...	251	620	147	1810	2500	38
Belgium ...	167	434	160	3670*	4140*	13
United Kingdom	251	419	67	4360	4950	14
Luxembourg	208	419	101	†	†	—
Switzerland	196	412	110	1660	2120	28
Netherlands	229	408	78	1730	2310	34
France ...	145	357	146	1860	2620	41
Ireland ...	153	326	113	N.a.	1260	N.a.
Austria ...	56	237	323	1320	1800	36
Germany ...	42	194	362	2090	3210	54
Italy	57	197	246	510	890	75
Greece ...	96	143	49	170	290	71
Portugal ...	65	105	62	230	340	48
Turkey ...	18	50	178	N.a.	250	N.a.
O.E.E.C. average	133	302	127	2000‡	2560	28‡
United States‡	2000	2600	30	8000	8100	1

* Incl. Luxembourg. † Incl. in Belgium. ‡ Approximate.

an investment estimated at between 1750 and 2250 million dollars.

If ancillary plant is included, another 500 million dollars must be added. Distribution and transport facilities are considered to represent an additional sum of nearly 1000 million dollars. Refinery capacity is considered to be sufficient for all present requirements of member countries.

In Table IV may be seen the flow balance of

TABLE IV—*Flow Balance of Oil in O.E.E.C. Countries in* 1955 (*million metric tons*)

Input of imported crude oil	96
Input of indigenous crude oil	7
Refinery throughput	103
Less refinery fuel and losses	8·8
Refinery output	94·2
Imports	14·9
Gross total	109·1
Less exports	6·6
Less bunkers	13·3
Less increase in stocks, &c.	2·6
Inland consumption	86·6

oil in 1955. Exports included 450,000 tons of motor gasoline, while imports involved some 4,000,000 tons of gas/diesel oil and 2·5 million tons of fuel oil. It is clear that it is becoming difficult for the refineries to match the European pattern of demand which is shifting towards the heavier fuels. Internal European trade increased to 22,000,000 tons in 1954 and remained at that figure during the following year.

In 1955, oil provided about 18 per cent of the European energy requirements, compared with coal, 74 per cent; natural gas, 1 per cent, and hydro-electricity, 7 per cent. Corresponding figures for the U.S.A. were: oil, 44 per cent; coal, 26 per cent; natural gas, 25 per cent, and hydro-electricity, 5 per cent. It is usual for general purposes to compare oil with coal on a basis of calorific value, the calorific values of oil and coal being approximately in the ratio 1·5:1. In many instances, however, the effective ratio is still more in favour of oil. The O.E.E.C. report quotes, among others, coal-oil parities of 1·5 for steam raising in power stations, 2 for central heating, 2·1 for open-hearth furnaces, 3 for marine propulsion, 5 for main line locomotives, and 12 for shunting locomotives.

In considering the future oil needs of Europe, the committee decided to make a careful study of the position to be expected for 1960. It is thought that, including bunkering, the demand will be about 153 million tons. Bunker consumption, the oil committee estimates, will run at 16,000,000 tons per annum by 1960 (13,000,000 tons fuel oil, 3,000,000 tons middle distillation). For 1975, the committee suggest an inland consumption of 310 million tons, plus 30,000,000 tons for bunkers, making a total of 340 million tons.

Production of crude oil and natural gas in various European countries is shown in Table V.

TABLE V—*Production of Crude Oil and Natural Gas—Western Europe in* 1955

Country	Crude oil (million metric tons)	Natural gas (million cubic metres)
Austria	3·67	766
France	0·88	274
Germany	3·15	240
Italy	0·20	3627
Netherlands	1·02	139
Turkey	0·18	—
United Kingdom	0·06	—
Total	9·16	5046

The greater part of European oil production has been in the German Federal Republic, Austria and the Netherlands, and it is considered that for these oil fields the annual increase in output until 1960 will not exceed 10 per cent. Natural gas production is centred on the Po valley; production there is expected to double itself by 1960 or even sooner, and may redouble by 1975.

World proved oil reserves at the end of 1955 were 7155 million metric tons in the Western Hemisphere, and 18,900 million metric tons in the Eastern Hemisphere, including 16,835 million metric tons in the Middle East. It should be noted that this estimate is on the conservative side. Another estimate of proved reserves at the end of 1954, presented to the U.S. Congressional Committee on Atomic Energy, showed a world total (exclusive of the Soviet bloc) of 44,000 million metric tons, 75 per cent of it in the Middle East. This figure is based on current real recovery costs; reserves recoverable at up to double present costs are estimated by the same authority at 70,000 million metric tons, representing 150 times the present annual rate of consumption outside the Soviet group. There is, therefore, no indication of any shortage of reserves within the period considered.

Sources of oil imports into Europe are shown in Table VI.

TABLE VI—*Gross Imports of Crude Oil and Finished Products into Europe* (*million metric tons*)

	1938	1950	1955
Crude oil :			
U.S.A.	4	2	—
Caribbean area	2	2	8
Middle East	4	32	88
Products :			
U.S.A.	7	1	2
Mexico	1	—	—
Caribbean area	12	11	11
East Indies	1	—	—
Middle East	4	8	2
Roumania and U.S.S.R.	4	—	2

Employment in the European oil industry is about 45,000 in the oil fields and 90,000 in the refineries. Largely owing to the small size of many units, the level of employment in both cases is above world average. It is likely that the numbers engaged in distribution are at least equal to those employed in refining. If technical and managerial personnel is included, the total employment figure is probably in the region of a quarter of a million.

Oil tonnage carried comprised over 40 per cent of world shipping traffic in 1948, and now amounts to about one half. Of the total oil tonnage, Western European imports and exports account for one third. World tanker tonnage amounts to 42,000,000 deadweight tons, of which 38,000,000 to 39,000,000 are considered to be available for normal oil transportation. About 23,000,000 tons were registered in 1956 under the flags of O.E.E.C. countries, a figure which is normally more than sufficient to carry the requirements of Western Europe; it includes tonnages of 8·1 million registered in the United Kingdom, 6·7 million in Norway, 1·8 million in Italy, 1·75 million in France, 1·55 million in Sweden, 1·5 million in the Netherlands, and 0·75 million in Denmark. Some 6·5 million tons are regis-

* *Oil—The Outlook for Europe.* A study by the Oil Committee. Paris: The Organisation for European Economic Co-operation, 2, rue André-Pascal, Paris (16e). Obtainable from H.M. Stationery Office, P.O. Box 569, London, S.E.1. Price 8s.

tered in the U.S.A., and 8 million in Liberia and Panama. Tonnage under construction for delivery within the next few years has recently been assessed at 18,000,000 tons. The size of new tankers has considerably increased since the war; at the end of 1950 there were about 250 tankers of 24,000 tons deadweight or over in service, with about 300 on order, including seven of over 50,000 tons deadweight. Oil transport through the Suez Canal rose from 6,000,000 tons in 1938 (17 per cent of all merchandise) to 69,000,000 tons in 1955 (64 per cent of all merchandise), of which 67,000,000 tons were moving north. If Europe's energy requirements are to be maintained at the lowest competitive price, it is considered essential to preserve the maximum flexibility in the sources of supply, so that competition between sources, both domestic and foreign, can operate to keep oil prices down.

Capital expenditure of the oil industry is extremely large. Excluding the Soviet area, world expenditure between 1951 and 1955 is estimated at nearly 35,000 million dollars, of which 24,000 million dollars were spent in the U.S.A. The corresponding amounts forecast for 1956–60 total nearly 50,000 million dollars, including nearly 33,000 million dollars in the U.S.A.; in 1961–65, it is thought, some 65,000 million dollars will be required, of which the U.S.A. will spend over 40,000 million dollars.

Estimated crude oil production figures are stated to be as follows (million metric tons) :—

Year	U.S.A.	Others (excluding Soviet bloc)	Total
1955	375	342	717
1960	444	489	933
1965	494	734	1228

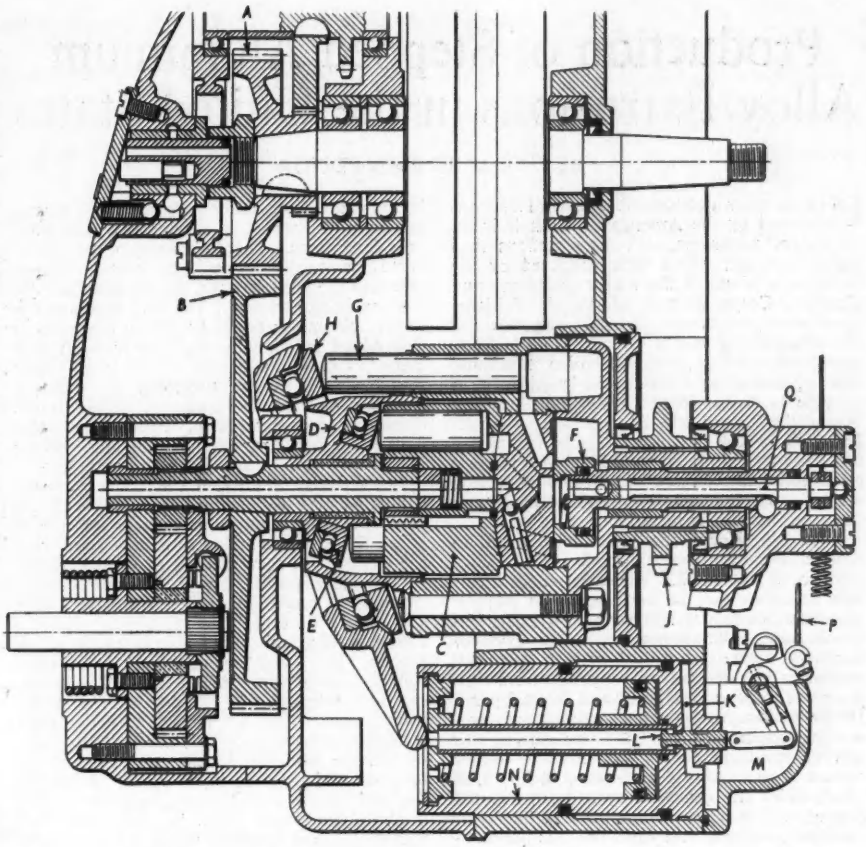
As a rough guide to the capital cost of expansion, it is stated that some experts quote a figure of about 120 dollars per annual ton of increased output, for outside the U.S.A. and at present costs and prices. This figure does not take into account the proportion required for maintenance of existing equipment (50 to 60 per cent of total investment in the U.S.A.). As a first approximation, it may be said that of the 120 dollars quoted, 40 dollars may be taken to be attributable to the cost of finding and producing crude oil, 30 dollars to refinery capacity, 30 dollars to transport, and 20 dollars to distribution facilities. No hard and fast figure can be quoted for the capital required for expansion in view of probable but quantitatively uncertain rises in price, and the shift in production to fuel oil which requires simpler refinery equipment. The figure quoted by the O.E.E.C. Commission for Energy is 7000 million dollars by 1975, sufficient to cover a European production of 33,000,000 tons a year, total imports of 210 million tons, and local refinery throughput of 190 million tons.

Hydrostatic Gearbox

British applications of hydrostatic principles to obtain infinitely variable reduction gears for vehicles have in the past effected the complete transmission hydraulically, but at the cost of heavy and expensive motors and considerable pumping losses. By confining the pump-motor combination to the function of a gearbox, S.p.A. Cambi Idraulici Badalini has evolved a compact unit with negligible losses in the direct drive condition.

The unit illustrated is incorporated in a 175 c.c. M.V. Augusta motor-cycle. The drive is taken by pinion *A* from the crankshaft, in the end of which can be seen a small swashplate pump to energise the transmission control system. The primary wheel *B* is keyed to a shaft, geared also to the kick starter, which is splined into the pump body *C*. The shaft and pump run within a casing *D* which includes the fixed pump swashplate *E*.

The oil passing through the pump is directed by drillings in the casing and a fixed valve block *F* to cylinders surrounding the casing. The plungers in these cylinders, such as *G*, bear upon a movable swashplate *H*, and the porting is such that the casing is driven in the same direction as the input shaft. As the motor displacement is diminished by reducing the angle of the swashplate, the speed of the casing rises and the output of the pump therefore falls; in the limit, the motor displacement is zero and the casing revolves at input speed. It can be visualised that the only loss in this case will be leakage past the plungers or seals, since there is no transfer of oil from one space to another. Final drive is from sprocket *J*.



Badalini hydrostatic transmission in unit with a single-cylinder motor-cycle engine

The swashplate is set by a simple hydraulic motor; servo oil pressure is fed into passage *K*, and movement of piston *L* directs the oil either through a restriction into the crankcase or through a drilling into space *M*. The resulting change in the pressure in this space will cause piston *N* to move right or left until the lands have again closed the oilways. The interior of the piston houses a hydraulic reservoir for the control system; since the maximum pressure is set by the designer, the operator cannot raise the "gear" ratio so high as to overload the engine. Change of ratio is effected by cable *P*.

Since there is no neutral in this transmission, zero output speed corresponding to maximum pump delivery, an additional control, seen at *Q*, is provided to short circuit the pump and allow starting and idling. Closing this valve brings the transmission into action.

The unit illustrated has a maximum reduction of 3·5 : 1, but this is, of course, at the designer's disposition. These units have been built in sizes ranging from 150 h.p. down to transmissions for motor scooters.

Conference on Nuclear Energy

A conference on nuclear energy for management is being organised by the O.E.E.C. European Productivity Agency (E.P.A.), assisted by the organisation's Nuclear Energy Secretariat. to take place in Paris from April 1–6, 1957. The purpose of the conference is to provide industrialists with information on the present stage of nuclear technical development and progress made in this field; the economic prospects offered to the European countries and their overseas territories by the development of this form of energy; the problems involved in the construction and operation of nuclear plant, especially for the metallurgical, chemical and mechanical engineering industries; and the opportunites for the industrial use of radio isotopes. The principal papers will deal with the various designs of reactor, the first nuclear power plants (Calder Hall in the United Kingdom, Marcoule in France, and Shippingport in the United States of America), the various elements of nuclear energy costs, special materials and equipment required by the nuclear industry, the present position of national programmes, and the action being taken at international level.

Papers will be read by members of the Atomic Energy Commissions of O.E.E.C. member and associate countries, and by industrialists directly concerned with nuclear work. Details may be obtained from O.E.E.C., Chateau de la Muette, 2, rue André-Pascal, Paris (16e).

Welding Exhibition at Utrecht

The Nederlandse Vereniging voor Lastechniek (Netherlands Welding Society), Zeestraat 62, The Hague, has announced that it is organising a Welding Exhibition, to take place at Utrecht from October 5 to 12, 1957. This exhibition, called the "Lastu 57," follows a similar one held in 1955 which had met with great success. This year's event will take place in the Margriethal, one of the buildings of the Utrecht Industries Fair. Simultaneously with the exhibition there will be held a two-day welding symposium, devoted to "The Metallurgy of the Welding of Steel." Like previous welding exhibitions, "Lastu 57" will be of an international character. For further information, as well as for hotel reservations, application should be made to the Society's Secretariat at the above address (telephone, 115974).

International Committee for Process Control

In connection with the third International Congress for Process Control, held in Heidelberg in September, a committee was elected by delegates from eighteen countries, for the purpose of intensifying the international co-operation in this field and of organising an interim international committee for process control and automation. The committee comprises one member each from Belgium, France, Germany, Poland, the U.S.A., and the U.S.S.R. Administrative matters have been placed into the hands of the VDI Section on Process Control, Verein Deutscher Ingenieure, Düsseldorf, German Federal Republic.

Production of Stepped Aluminium Alloy Extrusions in the United States

BY OUR AMERICAN EDITOR

IN recent years a considerable demand has been developed by the American aircraft industry for stepped extrusions, such as the sections illustrated herewith, which were produced by the Halethorpe Works of the Kaiser Aluminum and Chemical Corporation in Maryland. Initially, these developments were undertaken to overcome the volume and weight limitations of existing equipment. Placing material where it actually was required along the extruded length made it possible to design integral connecting lugs and obtain the longer lengths required. Aircraft designers quickly took advantage of the simplified design possibilities obtainable with stepped extrusions, and the economic advantages became evident with reduced raw material costs and decreased machining requirements.

A variety of methods have been devised to produce extrusions with variable cross-sections throughout the length. The early patent literature describes the use of tapered or stepped mandrels to produce tapered hollow extrusions which were split longitudinally to produce relatively simple sections. Extrusion dies with externally operated movable segments have been described to produce tapered and stepped parts. In the United States step extrusions are commonly produced at the present time utilising two sets of extrusion dies. The small or minor section is extruded first to the desired length, at which point the extrusion cycle is interrupted long enough to change dies to produce the major configuration. In most cases the dies are comprised of two segments to facilitate removal of the dies from the extruded part. The system illustrated in Fig 2 represents a schematic tooling arrangement and operational sequence for this method of producing stepped extrusions, as used by the Kaiser Aluminum and Chemical Corporation. A modification of this process is made possible thanks to improved press designs utilising a secondary locking arrangement to hold the minor section dies in position, as shown diagrammatically in Fig. 3. If single-piece dies are used, the minor die must be stripped off the end of the extruded section with the major die being threaded over the end of the minor part.

In working from the finished machined part to the stepped extrusion requirements, dimensional tolerances are of prime importance to ensure the ability to manufacture the desired part while avoiding an excess of stock to be removed. The tolerances applicable to stepped extrusions have not been standardised in the American industry at present, and those adopted by individual firms differ primarily from normal extrusion tolerances in straightness and step area dimensions. The straightness of the overall part is measured by its deviation from a reference line with the junction area, 8in on either side of the step being excluded. The straightness of the minor and major positions of the extrusion is determined individually with the junction area being excluded, and the minor and major positions are usually furnished to standard extrusion straightness tolerances. Due to the change of flow conditions in extruding the major and minor sections, the junction area usually presents the greatest straightening problems.

In the design of stepped extrusions produced from split dies the parting line positions should be considered not only from the tolerance standpoint, but from the ability to remove tools from the section. In some cases it may be necessary to provide slight draught angles on extended elements to accomplish this. While the major and minor sections may frequently have a common plane, this is not a requirement of the process. In all cases the major section must completely enclose the minor one. The cross-sectional tolerances of stepped extrusions are usually greater than normal, due to the inherent instability of split dies. It is generally necessary to provide sufficient machining stock on all surfaces of the section to be able to obtain the required accuracy of dimension and the surface finish requirements. This is particularly true regarding the dimensions which fall across the parting lines of the die. An additional tolerance is usually required on these dimensions due to the possible shifting of the die segments. With the abrupt change in flow pattern between the minor and major sections, areas of reduced mechanical properties are sometimes encountered at the junction extremities of the major section. In such cases the so-called dead metal areas not included in the direct flow path are subsequently removed by following certain recommended machining practices.

An additional consideration which must be recognised is the cross-sectional areas of the major and minor sections and the ratio of the major area to the minor area. These will have a marked influence on the mechanical properties obtainable. In normal aluminium extrusions the mechanical properties are dependent on the degree of working which the cast ingot received as measured by the reduction ratio. The reduction ratio is the ratio of extrusion press container area to the area of the part being extruded. It has been found that sub-standard mechanical properties are obtained in the American "7075" aluminium alloy when reduction ratios less than about 6 : 1 are used. When reduction ratios greater than about 30 : 1 are used for such a "7075" alloy excessive pressures are required. The designer of an extruded shape usually has no knowledge or control of the press container size on which a part is to be produced. To make the section producible under optimum conditions the major area to minor area ratio should not exceed 5 : 1. The mechanical properties of stepped extrusions, and particularly those of the junction area, have been the subject of many discussions. In some cases, due to the differences in areas and thicknesses, it will be necessary to work to two sets of allowable design stresses in the major and minor parts of the extrusion. As the manufacturer cannot vary extrusion temperatures rapidly enough to create ideal conditions for both the major and minor sections, it is necessary to use a compromise for the extrusion

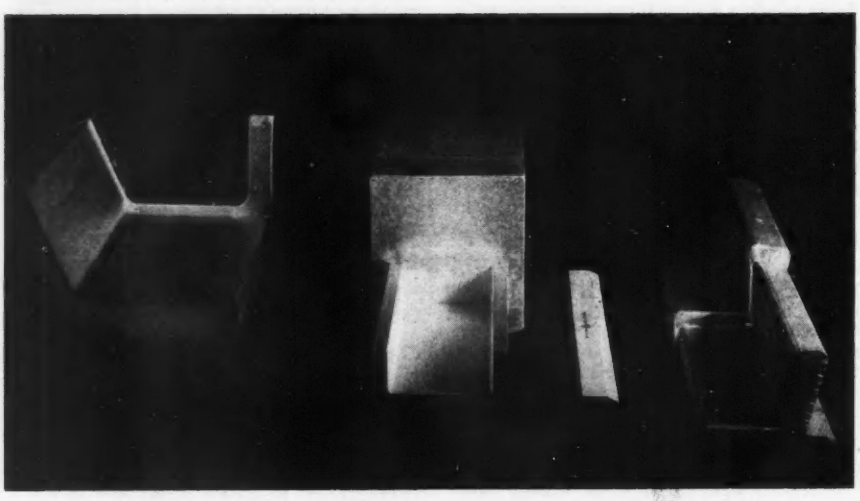


Fig. 1—Examples of stepped aluminium alloy extrusions produced by the Kaiser Aluminum and Chemical Corporation

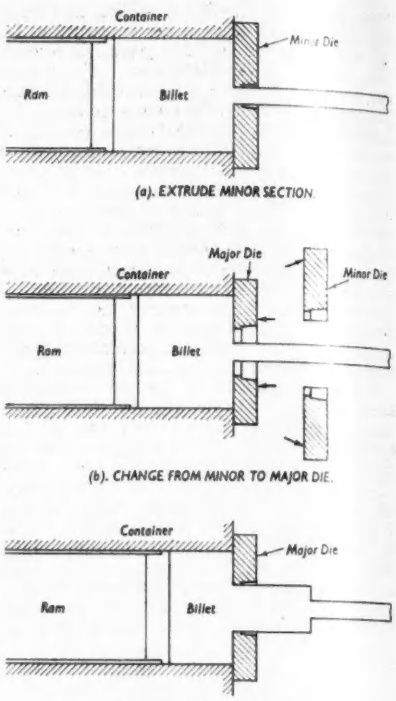


Fig. 2—Schematic tooling arrangement and operational sequence for step extrusion using two sets of dies

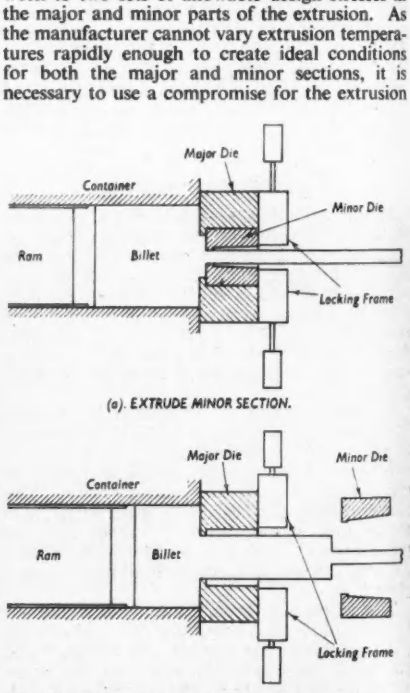


Fig. 3—Schematic tooling arrangement and operational sequence for step extrusion using a secondary locking arrangement

TABLE—*Mechanical Properties of* "7075-T6" *Aluminium Alloy Step Extrusions*

	Major part						Junction			Minor part					
	Thickness	Area	Testing direction	Ultimate tensile strength	Yield strength	Elongation	Ultimate tensile strength	Yield strength	Elongation	Thickness	Area	Testing Direction	Ultimate tensile strength	Yield strength	Elongation
	In	Sq. in		1000 p.s.i.	1000 p.s.i.	Per cent	1000 p.s.i.	1000 p.s.i.	Per cent	In	Sq. in		1000 p.s.i.	1000 p.s.i.	Per cent
Extrusion "A" ...	1·70	8·69	L	89·4	83·2	8·8	89·9	81·6	9·0	0·68	4·42	L	90·3	84·2	9·1
Extrusion "B" ...	3·06	16·05	L	89·4	82·1	8·0	—	—	—	0·72	5·98	L	90·2	84·8	10·0
Extrusion "C" ...	2·23	17·29	L	86·7	81·9	8·9	87·3	80·3	6·8	1·10	5·36	L	87·0	79·9	10·1
Extrusion "D" ...	1·98	21·28	L	88·8	81·2	10·2	88·0	78·8	9·5	1·58	12·11	L	91·6	83·4	9·2
			T	80·1	71·7	6·8	—	—	—	—	—	T	84·7	72·5	9·8
Extrusion "E" ..	4·66	28·95	L	86·8	81·2	11·0	—	—	—	1·40	10·63	L	91·0	84·4	9·0
			T	71·2	60·8	4·6	—	—	—	—	—	T	—	—	—
Extrusion "F" ...	5·32	29·32	L	88·2	75·8	9·5	79·5	71·9	4·0	0·485	3·30	L	90·4	84·3	12·0
			T	71·0	58·8	4·7	—	—	—	—	—	T	77·6	72·4	4·0

"L" = longitudinal. "T" = transverse.

of both parts. For example, it may be necessary to use an elevated extrusion temperature to start the minor section moving through the die. After the dies are changed to produce the major section this temperature may be considerably in excess of that required. From the standpoint of pressure requirements the major section has the advantage of a lower reduction ratio and the reduced billet length resulting from the extrusion of the minor part. The mechanical properties of certain representative "7075-T6" aluminium alloy stepped extrusions are shown in the accompanying table. In most cases it will be noted that the strength levels in the minor section are slightly greater than in the major, with the junction properties being equal to or slightly lower than those of the major section. The effect of higher than recommended major to minor area ratios will be noted in section *D*, where the ratio is 8·9 : 1. In this case the strength levels in the major section are considerably below those of the minor section in both the longitudinal and transverse directions with the junction properties falling below those of the major section. Investigations have been made to determine the mechanical property levels along a specific line from the front to the back of the extrusion.

The finishing operations for step extrusions follow, in general, the practices used for normal products. A representative sequence of operations for "7075" aluminium alloy step extrusions would be as follows: (*a*) extrude, (*b*) solution heat-treat, (*c*) stretch-straighten, (*d*) cut to length, and (*e*) age-harden. In the solution heat-treating operations "time at temperature" would be determined by the thickest element of the major section, which would probably be slightly longer than the time required for the minor section alone. The normal practice in stretching is to grip each end of the section in a hydraulic machine and to exert the necessary stretching force to straighten the part. Due to the differences in area, all of the permanent set in stretching is obtained in the minor section. It may be necessary in some cases to carry out straightening operations on the major section and the step area on a gag press. These operations should be performed before solution heat-treatment wherever possible to avoid leaving residual stresses.

As all step extrusions are machined to varying degrees, the problems of warping after machining are frequently encountered. This is probably aggravated by differential residual stress patterns in the minor and major sections of the extrusion. Experience obtained with plate has indicated that a 2 per cent permanent set stretch will virtually eliminate any warpage which occurs following machining operations. Experience obtained on extrusions indicates that similar results may be achieved by stretching. The optimum amount of stretching required on extrusions has not been clearly established.

A possible step extrusion which might be produced in the future would be an extrusion with a major section on both ends, allowing an integral fitting to be used on both extremities of the part. With the advancement of extrusion technology this appears possible and may become commonplace in the future. Many of the present step extrusions are used for aircraft spar cap applications. Such requirements for step extrusions can be visualised with the major portion being situated in the centre of the part. Furthermore, many applications for large tubular parts are being developed in the missile field. Internal and external steps on these tubes can be obtained through the use of a stepped mandrel combined with the techniques normally used to produce step extrusions. The use of a stepped mandrel has previously had the limitations of allowing only unidirectional stepping of the interior surface. With modern extrusion equipment it is possible to place these steps at either end of the tube or in the centre, as desired. In other areas of development of extruded products for aircraft usage, integrally stiffened panels are now becoming commonplace. These products are available in America in widths of up to 25in extruded in a flat configuration. The accompanying illustration shows such a panel section being extruded on the 8100-ton "Loewy" hydraulic extrusion press at the Halethorpe Works of the Kaiser Aluminum and Chemical Corporation. Current development work indicates that even greater widths are available from existing equipment. Frequently this section is now being extruded in a "V" or tubular configuration to obtain greater widths. A great deal of effort has been expended in attempting to flatten tubular extrusions to obtain the desired flatness required of aerodynamic surfaces.

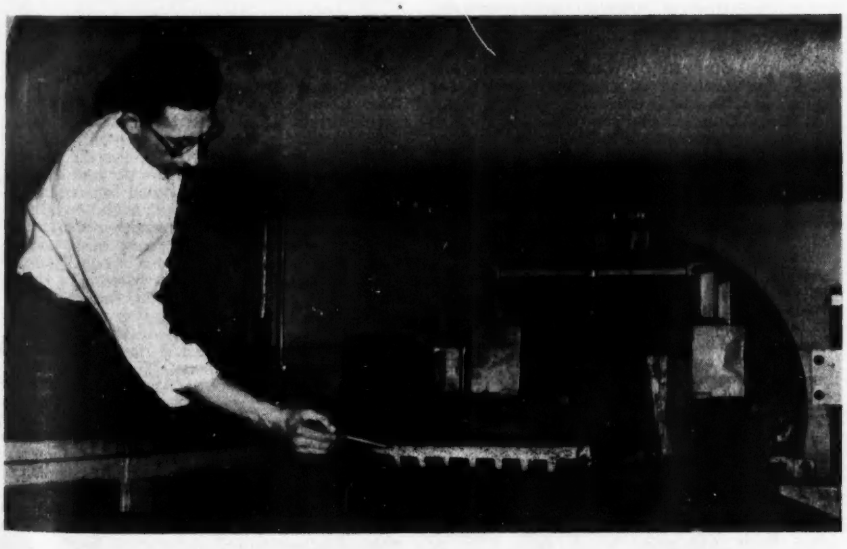


Fig. 4—Extrusion of an integrally stiffened aircraft panel section in a flat configuration on an 8100-ton water-hydraulic extrusion press

Apparatus for Wavelength Determination

The determination of wavelengths with accuracies to one part in one million can be obtained with a new mercury-198 source and microwave exciter unit, which has been developed by Baird Associates, Incorporated, of Cambridge, Massachusetts. This apparatus is built for use in high-dispersion interferometry, greatly facilitates the determination of wavelengths, and provides a higher level of accuracy in analysis. The mercury-198 source is a fused quartz electrodeless lamp, 6mm in diameter and 14cm long, utilising about 0·4 mg of mercury-198 prepared by the transmutation of gold in an atomic pile. Argon is used as a buffer to enhance mercury excitation. As shown in the accompanying illustration, the exciter is a portable unit,

Baird apparatus for wavelength determination with mercury-198 source

operating at a wavelength of 12·2cm in the 2400–2500 megacycle band, and supplied from a 60 c/s, 115V a.c. power source. Radio-frequency energy is generated in a continuous-wave magnetron oscillator and carried in a flexible coaxial cable to the director, which concentrates the external radiation on the lamp. The device has a maximum power output of 125W. The relative power output is indicated by a meter on the front panel.

High-voltage d.c. for the magnetron is provided by an a.c.-operated power supply which includes separate anode and cathode transformers, two rectifier valves and a filter circuit. The input to the high-voltage transformer is controlled by a time-delay relay, a timer and a "Variac" unit which controls the r.f. power output to the magnetron. Front panel preheat and power switches control the cathode and anode power, respectively, with adjacent lights provided to indicate the switch positions. An a.c. blower supplies cooling air throughout the cabinet, which measures 15in by 10in by 11in.

Personal and Business

Appointments

MR. N. H. PAYNE has been appointed a director of Dowty Fuel Systems, Ltd.

MR. ERIC DENNIS has been appointed a director of Automotive Engineering, Ltd.

MR. F. ERIC L. BACHE has been appointed chairman of Geo. Salter and Co., Ltd.

MR. R. T. DE POIX has been elected chairman of the Zinc Development Association for 1957.

MR. D. A. BISHOP has been appointed export manager of F. E. Weatherill, Ltd., Welwyn Garden City.

MR. HUGH MICHAEL SELLS has been appointed field manager of the Scottish district of British Oxygen Gases, Ltd.

MASSEY-HARRIS-FERGUSON, Ltd., has announced that the Marquess of Abergavenny and Lord Weeks have been appointed directors.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., has announced the appointment of Mr. C. Murray, A.M.I.E.E., as manager (overseas).

THE BRITISH TRANSPORT COMMISSION has announced the appointment of Mr. D. Murray as assistant traffic adviser (freight) at the Commission's headquarters.

MR. D. N. DE MATTOS, A.M.I.E.E., has been appointed manager of the Bristol and S.W. district office of the British Thomson-Houston Company, Ltd.

GENERAL REFRACTORIES, Ltd., has announced the appointment of Mr. H. Pattison as deputy secretary. Mr. Gordon Ledingham has been appointed chief engineer.

THE BENNETT FURNACE AND ENGINEERING (SOUTH) COMPANY, Ltd., states that Mr. A. C. Parker has been appointed commercial manager of the Bennett group of companies.

CLIFFORD CULTIVATORS, Ltd., West Horndon, Essex, announces the following appointments: Mr. E. N. Griffith, chairman, and Mr. T. Barraclough, Mr. P. Coleclough, and Mr. J. A. Smith, directors.

MR. W. PITKETHLY has been appointed manager of the purchases and supplies department of the British Aluminium Company, Ltd., in succession to Mr. R. L. C. McDonald, who is retiring on February 2.

MR. C. J. HIND has been appointed chief engineer (engines) of Ruston and Hornsby, Ltd., in succession to Mr. J. D. Thorn, who has taken up a post with the United Kingdom Atomic Energy Authority Industrial Group.

A. V. ROE AND CO., Ltd., has announced that Mr. R. V. Browne is to head its new weapons research establishment at Salisbury, South Australia. Mr. Browne has already left for Australia to take up his appointment.

THE MINISTRY OF SUPPLY states that Colonel G. C. Richards has been appointed deputy director of the Military Engineering Experimental Establishment, Christchurch, and has been granted the acting rank of Brigadier.

MR. F. P. BOLER has been appointed assistant manager of supply and inventory, purchasing and traffic, of C.I.M.A., the manufacturing affiliate in France of the International Harvester Company of Great Britain, Ltd.

MR. V. S. RISOE has been appointed a director of Associated Electrical Industries Overseas, Ltd., and has resigned from the boards of Associated Electrical Industries (India) Private, Ltd., and Associated Electrical Industries Manufacturing Company Private, Ltd.

THE CONSETT IRON COMPANY, Ltd., announces the following appointments as representatives: Mr. Harold W. I. Rees, Midlands, in succession to Mr. J. H. Clark, who has retired, and Mr. G. C. Coatsworth, Glasgow, in succession to Mr. R. G. Macintyre, who has retired.

THE MINISTRY OF TRANSPORT AND CIVIL AVIATION states that Captain D. W. McNab has been appointed principal officer of the marine survey service in the South and South West of England district. He succeeds Captain H. J. H. Bulford, who has retired from the department.

Business Announcements

MR. T. P. CHEW, manager of the tool department of Richard Lloyd, Ltd., has retired after forty-four years in the service of the company.

MOXEY CONVEYOR AND TRANSPORTER COMPANY, Ltd., 13, Augustus Road, Birmingham, 15, states that it has changed its name to Moxey, Ltd.

THE NATIONAL COAL BOARD announces that Mr. E. H. D. Skinner will vacate the office of chairman of the Durham Division on February 28.

HALE, HAMILTON AND CO., Ltd., states that the valve and pressure controller business of the company has been taken over by Hale, Hamilton (Valves), Ltd.

MR. ARNOLD CARR, assistant managing director of Thos. W. Ward, Ltd., is visiting Australia in connection with group activities. He is travelling in both directions via the U.S.A.

MR. JOHN OLDHAM, chairman and joint managing director of Oldham and Son, Ltd., has left this country for a two months' visit to the company's subsidiaries in South and Central Africa.

WOLF ELECTRIC TOOLS, Ltd., states that its head service department has moved to Newlon Works, Stanlake Villas, Stanlake Road, Shepherds Bush, London, W.12 (telephone, Shepherds Bush 4414–6).

ATLAS COPCO has announced the formation of a new company, Atlas Copco Congo S.C.R.L., with headquarters at Elisabethville, Belgian Congo. Mr. Mario Pellegrino has been appointed managing director.

TRIPLEX SAFETY GLASS COMPANY, Ltd., has announced that Field Marshal Viscount Alanbrooke, K.G., has beeen compelled, on medical advice, to tender his resignation as deputy chairman and director.

MR. J. M. BROOKE, M.I.E.E., managing director of the Venner Group of companies, has left this country to investigate the possibility of setting up a company to manufacture Venner products in Australia.

THE RT. HON. R. R. STOKES, M.P., chairman and managing director of Ransomes and Rapier, Ltd. and managing director of Cochran and Co. (Annan), Ltd., has left this country for a short visit to Beirut and Baghdad.

ARTRITE RESINS, Ltd., 44/46, Kingsway, London, W.C.2, has been formed to provide a service to the reinforced plastics industry, and to that section of industry which is interested in the production of structural plastics.

WHITEHOUSE INDUSTRIES, Ltd., states that it is opening new offices for its Philidas division at 44, Hertford Street, London, W.1 (telephone, Grosvenor 1402–3). Pollard Bearings, Ltd., is opening new offices at the same address.

THE BALDWIN INSTRUMENT COMPANY, Ltd., states that the name "Atomat" has been registered as a trade mark (No. 755,154). It will apply to Beta, Gamma, Bremsstrahlung and X-ray thickness gauges as well as to the transverse profiler.

MR. T. POOLEY, sales director of Expandite, Ltd., is leaving the country on February 4, to visit the subsidiary company Expandite (South Africa), Ltd., Johannesburg. On his return trip he will visit the company's distributors in Rhodesia and East Africa.

THE CONSOLIDATED PNEUMATIC TOOL COMPANY, Ltd., has announced the formation of a new company, The Consolidated Pneumatic Tool Company of Central Africa (Pvt.), Ltd., to develop its business in the Federation of Rhodesia and Nyasaland. Mr. R. G. Wells has been appointed managing director.

THE STEEL COMPANY OF WALES, Ltd., announces that it has concluded an agreement with Kaiser Engineers, of Oakland, California, granting it the right to make, use, sell and sub-license to others the P.T. oxygen gun equipment, which has been patented in this country by the Steel Company of Wales. The rights granted apply throughout the world with the exception of Europe.

Contracts

ACROW ENGINEERS (EXPORT), Ltd., has secured a contract for the supply of steel formwork for the erection of pumping stations, tank farms and port terminal installations for a NATO project in Turkey. The work is being carried out as a joint venture by Costain-John Brown, Ltd., of London, and Williams Bros., of Tulsa, Oklahoma, and the Acrow formwork contract is valued at £131,000.

TAYLOR WOODROW (WEST AFRICA), Ltd., has received a £3,500,000 contract for a wharf extension at Port Harcourt, Nigeria, from the Government of the Federation of Nigeria, through the Crown Agents for Oversea Governments and Administrations. The works comprise the construction of a wharf extension, 1550ft long, to provide three additional deep-water berths, three single-storey transit sheds, 350ft by 150ft, a single-storey warehouse, 400ft by 150ft, various store and office buildings, road and rail tracks. The work is due to be completed by June, 1960, although it is anticipated that two of the new berths can be brought into operation before that date. The consulting engineers are Messrs. Coode and Partners, of London.

THE CENTRAL ELECTRICITY AUTHORITY has placed contracts during the past month for power stations, transforming stations and transmission lines, amounting in the aggregate to £16,920,400. The principal contracts include: Drakelow "B" power station, Burton-on-Trent, two 120MW turbo-generators, condensing and feed heating plants (C. A. Parsons and Co., Ltd.), and 3300V and 415V works auxiliary switchgear (A. Reyrolle and Co., Ltd.); High Marnham power station, Tuxford, one 210MVA, 275kV generator transformer (English Electric Company, Ltd.); Willington "B" power station, near Derby, two 200MW turbo-generators, condensing and feed heating plants (Metropolitan-Vickers Electrical Company, Ltd.); Rugeley power station, two 120MW turbo-generators (C. A. Parsons and Co., Ltd.); Aberthaw power station, three 100MW reheat turbo-generators, feed water plant, condensing plant and auxiliary apparatus (C. A. Parsons and Co., Ltd.); Finchley substation, two 90MVA, 132/33kV transformers and one 60MVA, 66/33kV transformer (Hackbridge and Hewittic Electric Company, Ltd.); Melksham substation, 275kV switchgear (Metropolitan-Vickers Electrical Company, Ltd.).

Miscellanea

TABULAR SUMMARY OF CIVIL ENGINEERING CONTRACTS.—In the 1956 edition of the *Tabular Summary of Civil Engineering Contracts*, published as a supplement with THE ENGINEER of December 21 last, there is an error in the section enumerating the C.E.A.'s power station contracts, at the top of page XXX. The entry on the first line of that page, namely, a contract of £1,500,000 for a boiler house, turbine house and chimney, for which the contractor is J. Morgan (London), Ltd., refers to Brighton "B" power station, and not Connah's Quay, Chester, as the alignment indicates. The second line on the page, "reclamation, foundations, superstructure," &c., refers to Connah's Quay. In both cases the consulting engineers are Messrs. L. G. Mouchel and Partners.

NEW OFFICES OF FERGUSON-PAILIN, LTD.—To meet the need for continued expansion in all its manufacturing departments, Ferguson-Pailin, Ltd., recently opened new offices to accommodate staff engaged in engineering, design, drawing-office and research work. These offices are housed in a modern four-storey brick building which faces the Edge Lane approach to the company's works at Higher Openshaw, Manchester. The new building consists of a central block flanked, on each side, by wings which can accommodate future extensions. Other recent additions to the establishment at Higher Openshaw include new wood shops, for patternmaking as well packing cases, packing case manufacture and general joinery; new bays extending the switchgear factory floor space; and a boiler house for supplying the works with its heat and process steam requirements.

ANNUAL LUNCHEON OF BIMCAM.—The annual luncheon of the British Industrial Measuring and Control Apparatus Manufacturers' Association was held in London on Tuesday, January 8. In his speech proposing the toast of "The Association," Mr. F. J. Erroll, then Parliamentary Secretary to the Board of Trade, said that, despite the setbacks experienced in 1955, the past year had shown an overall trade improvement. During the first eleven months of 1956 imports had been only 1 per cent higher in value than the previous year, whilst exports were 10 per cent higher in value and 6 per cent higher in volume. This country was second to none in producing new ideas and techniques, as had been shown by its achievements in many directions. Calder Hall was an example of this pioneering work, and the Association was representative of a branch of industry which played a very important part in the success which had been achieved in the field of nuclear energy. He mentioned that the Board of Trade had recently set up an Instrument Advisory Committee, which would provide a useful liaison between the industry and the Government. In his response, Mr R. G. Kent, chairman of the Association, mentioned the growth of the exports of the firms in the Association and pointed out that they were supplying water meters to almost every country in the world with a running water supply. Mr. L. S. Yoxall, the president of the Association, thanked the Federation of British Industries for the co-operation and help it had given to the Association, and said that the industry looked forward to success for the Instruments, Electronics and Automation Exhibition to be held in May next in London.

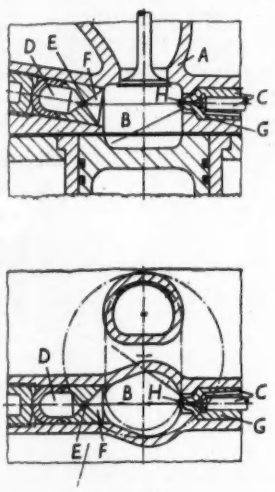
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

INTERNAL COMBUSTION ENGINES

764,651. February 11, 1955.—INTERNAL COMBUSTION ENGINES WITH FUEL-INJECTION AND ENERGY CELL, Lanova A.G., 16, Bahnhofstrasse, Zurich, 1, Switzerland.

The invention relates to internal combustion engines having within the cylinder head a combustion chamber open towards the cylinder space and offset in relation to the axis of the cylinder, an energy cell opening at one side into the combustion chamber, and a fuel-injection nozzle arranged at the opposite side of the chamber to the opening of the energy cell, the fuel-injection nozzle being so positioned that the fuel jet is directed towards the opening into the energy cell. As shown in the drawing, the cylinder head *A* has a combustion chamber *B* open towards the cylinder and offset in respect of the centre line, as shown in the lower view. An elongated injection nozzle *C* horizontally disposed within a cavity of the cylinder head projects into the combustion chamber. At the opposite side of the combustion chamber, an energy cell *D* is arranged so that its narrow orifice *E*, with its flared opening *F*, faces the injection nozzle. The piston is shown in its upper dead centre position. For obvious reasons, a certain distance must be left between the end wall of the piston and the wall of the cylinder head which faces the piston. Thus a gap



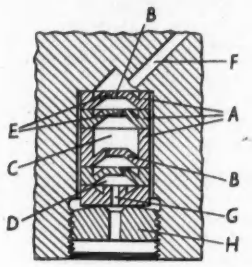
No. 764,651

is formed which extends from the transfer opening of the combustion chamber *B* to the cylinder wall, and although the gap is narrow, it includes a considerable space in view of its great depth at right angles to the axis of the fuel nozzle, as shown in the lower view. Therefore, this gap contains a considerable proportion of the combustion air. The body *G* of the injection nozzle has a reduced discharge end *H* which projects into the combustion chamber. As a result of the long discharge channel, the fuel is well guided so that a well-defined fuel jet is formed and directed towards the flared opening into the energy cell *D*. The nozzle body *G* has an additional bore at the point where the reduced discharge end of the nozzle begins, and this bore is so inclined to the longitudinal axis of the nozzle that the fuel jet is directed against the gap between the end wall of the cylinder head and the piston crown. Thus a fuel cloud is formed at the entry into the gap and is forced to enter the gap as soon as combustion is initiated and a pressure increase is produced with the result that the air within the gap becomes mixed with fuel and takes part in the combustion process at the proper time.—*December* 28, 1956.

COMPRESSORS

764,379. February 23, 1955.—THE STARTING OF ELECTRICALLY DRIVEN COMPRESSORS, Siemens Societa Per Azioni, 29, Via Fabio Filzi, Milan, Italy. (*Inventor: Szaniszlo Stefano.*)

The invention relates to a device for facilitating the starting of electrically driven compressors, particularly those used in refrigeration, air-conditioning and like plant. The object of the invention is to provide a device without any movable parts, which works completely automatically. As shown in the drawing, the device comprises a conduit having a series of abrupt variations in its internal diameter, one end of the member being constantly in communication with the compression chamber and the other constantly in communication with the atmosphere or with the suction chamber of the compressor. In it a number of elements *A* are stacked one on top of another to form a column. Each consists of a small, hollow cylinder, preferably of metal, the hollow chamber of which is provided with a partition wall *B*, convex at the top, so that it will divide the chamber into an upper chamber *C* and a lower chamber *D*. Each partition wall has a passage *E* through it which is narrow in comparison with the width of the chambers. Of the two terminal elements *A* in the column, the upper element is in communication, through a duct *F*, with the compression chamber of the compressor, while the lower element is in communication, through a duct *G*, with the atmosphere or with a chamber connected to the suction chamber of the compressor.



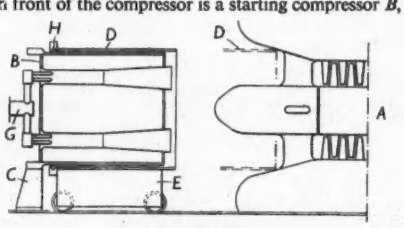
No. 764,379

In the case of a sealed unit, the passage *G* is in communication with the interior of the casing. The device can be housed in a bore in the housing of the motor compressor unit, where it is secured by means of a screw *H*, which, at the same time, holds together the elements. The method of operation is as follows: On starting, during the compression stroke, the compressor piston compresses the cooling gas remaining in the cylinder. The speed of advance of the piston is low and the compressed gas can escape to a large extent through the duct *F* and the series of chambers connected to it. After the first inner dead centre has been passed comparatively easily, the unit increases its speed and more gas escapes through the series of chambers during each compression. But the duration of the compression strokes becomes shorter and shorter and the speed at which the gas is forced through the series of chambers becomes greater. As the gas passes through the chambers, a number of conversions of kinetic energy into potential energy and vice versa take place according to known laws, and are necessarily associated with energy losses. As the speed of the gas increases, these energy losses increase very rapidly and cause a corresponding reduction in the amount of gas forced through during each compression. Practical experiments have shown that during normal running the offtake of gas by the device, according to the invention, does not exceed 3 to 4 per cent. This value applies to the coolants which are generally used in refrigerators. With air which is lighter, gas losses are about twice as much. The invention can be carried out in many ways. In the arrangement described, the narrow apertures *E* are staggered in relation to one another and the partition walls *B* are arched upwards. The main object of this is to ensure that any solid particles entrained by the gas are retained in the deeper part of the chambers formed by the partition walls, thus reducing the risk of blockage.—*December* 28, 1956.

GAS TURBINES

763,895. January 7, 1955.—GAS TURBINES, Svenska Turbinfabriks Aktiebolaget Ljungström, Finspong, Sweden.

The invention relates to gas turbines which are started by supplying compressed air from a starting compressor to the compressor of the turbine, and its object is to provide means for effecting a transient communication, free from leakage, between the two compressors during the starting period. In the drawing, *A* is the compressor of a stationary gas turbine. In front of the compressor is a starting compressor *B*,



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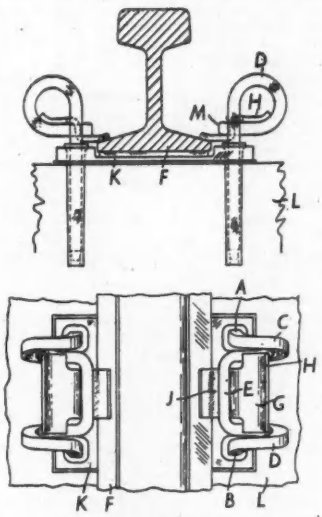
comprising a jet compressor rigidly arranged with relation to the compressor, on a foundation *C* at such a distance from the compressor as not to interfere with the entrance of air to it after the starting period is ended. The compressor *B* is provided with a surrounding cover *D* supported by a carriage *E*, the wheels of which run on rails so as to allow the cover to be moved towards and away from the air intake of the compressor *A*. When the gas turbine is to be started the cover *D* is displaced by means of a control device, by the action of compressed air towards the compressor *A* into the position indicated by dotted lines. Air under pressure is admitted through a conduit *G* to the jet compressor *B*, which delivers highly compressed air to the compressor *A*, causing it to start rotating. When the gas turbine has attained such a speed as to be capable of driving itself the cover *D* is automatically retracted to its initial position covering the jet compressor, thereby allowing air to be sucked into the compressor *A* through the space between the two compressors. At its end remote from the gas turbine the cover *D* is provided with a packing *H* for sealing the space between the cover and the jet compressor so as to prevent leakage of air by this passage during the starting period. Instead of a jet compressor a motor-driven compressor may be used.—*December* 19, 1956.

RAILWAY ENGINEERING

764,404. January 6, 1955.—FASTENING RAILS TO SLEEPERS, Everts & Van Der Weyden N.V., 14, Binnen Parallelweg, Helmond, Holland.

The resilient spikes shown in the drawing each comprise two shanks *A* and *B* connected together by means of helical loops *C* and *D*, and a bridge portion *E*. The shanks of the fastenings on either side of a rail *F* are spaced apart so that the bridge portions *E* are adjacent the foot of the rail, but do not bear upon it. A clip *G* of T-shape is inserted in each spike so that the ends *H* of the cross member engage on the lower part of the inside of the loops *C* and *D*, and the stem *J* engages along its full width on the underside of the bridge portion *E* and on the top surface of the bottom of the rail. The clip *G* may be manufactured by stamping from sheet metal and, as shown, the stem may have a cranked part or, alternatively, each arm of the cross member may have a cranked part. To enable the stem *J* to engage above the bottom of the rail it is necessary to raise the bridge portion *E*, so tightening the helical loops *C* and *D*, so that on release after insertion of the clip *G*, the loops tend to unwind and the bridge



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portion *E* exerts a downward force on the stem *J* which transmits the force to the bottom of the rail, whereby both the rail and the clip are clamped on a sleeper. If parts of the loops are lifted by means of a claw wrench the shanks of the spike remaining fully embedded in the sleeper, the clip may be readily removed. The drawing shows the application of fastenings to a rail seated on and laterally supported by a sole plate *K* on a concrete sleeper *L*. The loops *C* and *D* are so shaped that the face *M* of the bridge portion *E* extends on the rail side of the shanks *A* and *B*. Alternatively, the rail may be seated on a resilient pad on a sleeper in which case the rail is supported laterally by the shanks of the spikes, which are inserted in the sleeper immediately adjacent the bottom of the rail and the face of the bridge portion is maintained away from the rail. The clip functions as an extension of the bridge portion of the spike transmitting the downward pressure from the spike to the rail bottom and in so doing is anchored in place. In all cases the bridge portion of the spike is arranged to be clear of the rail so that on removal of the clip the rail may also be removed simply and quickly and without impairing the grip of the spike on the sleeper.—*December* 28, 1956.

Launches and Trial Trips

PORTIA, trawler; built by Smith's Dock Company, Ltd., for Hellyer Brothers, Ltd.; length overall 210ft 6in, length between perpendiculars 190ft, breadth moulded 34ft 6in, depth moulded 17ft 10in; fish-room capacity 17,300 cubic feet; one set of English Electric diesel-electric machinery, two 357kW, 255V generators in wings, and one 467kW, 340V generator in centre line, all diesel-driven; on top of each generator is a 60kW chain-driven generator, one propulsion motor of 1500 s.h.p. at 160 r.p.m.—Trial, October 23.

ATLANTIC KNIGHT, oil tanker; built by the Blythswood Shipbuilding Company, Ltd., for the Ocean Tanker Line, Ltd., Monrovia; length between perpendiculars 565ft, breadth 76ft 7in, depth 41ft 2in, deadweight 22,500 tons; nine centre and eighteen cargo oil compartments, one main cargo pump room, three 680 tons per hour turbine-driven horizontal centrifugal cargo pumps, two 180 tons per hour stripping pumps; one set of double reduction geared turbines by David Rowan and Co., Ltd., 8000 s.h.p. at 105 propeller r.p.m., two Babcock and Wilcox boilers supply steam at 450 lb per square inch and 780 deg. Fah.—Trial, October 31.

NARDANA, cargo liner; built by Barclay Curle and Co., Ltd., for the British India Steam Navigation Company, Ltd.; length 514ft, breadth 67ft 6in, depth to shelter deck 41ft 8in, gross tonnage 10,000; six cargo holds, twenty derricks to lift 6 tons and 15 tons, electric winches, four 300kW diesel-driven generators; one set of Parsons triple expansion geared turbines, 116 propeller r.p.m., two water-wall boilers supply steam at 475 lb per square inch, 750 deg. Fah.—Trial, November 2.

ATLANTI-M. LIVANOS, cargo ship; built by the Burntisland Shipbuilding Company, Ltd., for Fomentador Companiə Naviera S.A., Panama; length between perpendiculars 435ft, breadth 59ft 9½in, depth moulded to upper deck 39ft 6in, deadweight 11,850 tons; five cargo holds, one 30-ton and ten 10-ton derricks; electric winches, three 150kW diesel-driven generators, one 35kW generator; Kincaid-B. and W. two-stroke, single-acting, diesel engine, seven cylinders 620mm diameter by 1870mm combined stroke, 5500 b.h.p. at 120 r.p.m.—Trial, November 2.

CARTAGO, refrigerated cargo ship; built by Cammell Laird and Co. (Shipbuilders and Engineers), Ltd., for Empresa Hondurena de Vapores S.A., Honduras; length between perpendiculars 425ft, breadth moulded 59ft, depth moulded to upper deck 36ft, draught 26ft; four main cargo spaces, eight 5-ton derricks, electric winches, three 400kW turbine-driven alternators, one 75kW diesel-driven alternator; one set of two-cylinder, double reduction geared turbines, 9000 s.h.p. at 125 r.p.m., three Babcock and Wilcox single pass boilers supply steam at 600 lb per square inch and 850 deg. Fah.—Launch, November 2.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Sat., Jan. 19.—LIVERPOOL BRANCH: Visit to Mersey Tunnel, Control and Ventilating Station, 2.45 p.m.——OXFORD, READING AND DISTRICTS BRANCH: Regents Park College, Pusey Street, Oxford, "Interference Suppression," A. P. Hale, 6.30 p.m.

Wed., Jan. 23.—NOTTINGHAM BRANCH: E. Midlands Electricity Board, Smithy Row, Nottingham, "The Nature of Plastics," H. H. Lusty, Lecture and Film, 7.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., Jan. 23.—LONDON SECTION: Kingsley Hotel, Bloomsbury Way, London, W.C.1, Morning Session, "The First Ten Years of the National Coal Board," Noel Gee, 10.30 a.m.; Afternoon Session, "The Effect of Coal Characteristics on the Operation of Mechanical Stokers," D. C. Gunn, 2.30 p.m.

COVENTRY ENGINEERING SOCIETY

Thurs., Jan. 24.—Coventry Victor Social Club, Coventry, "Newer Fibres and Fabrics," E. P. Sharman, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Fri., Jan. 25.—BIRMINGHAM CENTRE: Regent House, St. Phillip's Place, Colmore Row, Birmingham, "Lighting of Educational Institutes," A. G. Sheppard Fiddler, 6 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Jan. 18.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, "Arc Welding," lecture and film, F. A. Thomas, 7.30 p.m.

Tues., Jan. 22.—S. WALES BRANCH: S. Wales Engineers' Institute, Park Place, Cardiff, "The Factories Act," R. H. Thompson, 7.15 p.m.

Thurs., Jan. 24.—MERSEYSIDE AND N. WALES BRANCH: Exchange Hotel, Liverpool, "Method Study," G. St. G. Wheeley, 7.15 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., Jan. 22.—WALES AND MONMOUTH BRANCH: Whitehead Institute, Newport, Joint Meeting with Newport Metallurgical Society, "Mechanism of the Solidification of Cast Iron," H. Morrogh, 7 p.m.

Wed., Jan. 23.—BIRMINGHAM BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, 3, "Methods Engineering as Applied to the Steel Foundry," E. Daybell, 7.15 p.m.

Fri., Jan. 25.—WALES AND MONMOUTH BRANCH: Engineers' Institute, Cardiff, "Flow of Metal into Moulds," Film, 6 p.m.——FALKIRK SECTION: Temperance Cafe, Lint Riggs, Falkirk, "Production of Alloy Iron Castings," D. Fleming, 7.30 p.m.

Sat., Jan. 26.—E. MIDLANDS BRANCH: College of Arts, Derby, "The Production of Castings for Aircraft Engines," C. W. Hicks, 6 p.m.

INSTITUTE OF FUEL

Wed., Jan. 23.—Institution of Civil Engineers, Great George Street, London, S.W.1, "The Chemistry of Coal and its Relation to Coal Carbonisation," I. G. C. Dryden, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., Jan. 21.—S. WALES SECTION: S. Wales Institute of Engineers, Park Place, Cardiff, Annual General Meeting, 6 p.m. W. OF ENGLAND SECTION: York House Hotel, George Street, Bath, "Some Considerations of Wear in Marine Gearing," W. H. Darlington, 7.30 p.m.

INSTITUTE OF METALS

Mon., Jan. 21.—SHEFFIELD LOCAL SECTION: The University, St. George's Square, Sheffield, 1, "Research Work in the Department of Metallurgy, the University of Sheffield," A. G. Quarrell, 7.30 p.m.

INSTITUTE OF NAVIGATION

To-day, Jan. 18.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "The All-weather Operation of Transport Helicopters," P. A. Hearne, 5.15 p.m.

INSTITUTE OF PHYSICS

To-day, Jan. 18.—NON-DESTRUCTIVE TESTING GROUP: 47, Belgrave Square, London, S.W.1, "Radiological Protection—the Present View," E. E. Smith, 6.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Tues., Jan. 22.—N.E. CENTRE: Three Tuns Hotel, Durham City, "High Pressure and Syndromic Lubrication Systems," W. T. Kay, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Fri., Jan. 25.—N.W. BRANCH: Grand Hotel, Manchester, Annual General Meeting, 3.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Fri., Jan. 25.—YORKSHIRE ASSOCIATION: Hotel Metropole, Leeds, "Organisation and Control of Highways Maintenance," W. J. Hiscock, 6.15 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Jan. 18.—S. MIDLAND CENTRE: Town Hall, Birmingham, Faraday Lecture, "Nuclear Energy," T. E. Allibone, 7 p.m.

Sat., Jan. 19.—LONDON GRADUATE AND STUDENT SECTION: Visit to Arthur Guinness Brewery, Park Royal, London, N.W.10, 10 a.m.

Mon., Jan. 21.—WESTERN SUPPLY GROUP: Engineering Department, University of Bristol, "An Introduction to Nuclear Power Generation," D. F. Welch, 6 p.m.——LONDON GRADUATE AND STUDENT SECTION: Savoy Place, London, W.C.2, "Television Film Recording," E. J. Stocks, 6.30 p.m.

Tues., Jan. 22.—N. MIDLAND CENTRE: Central Electricity Authority, 1, Whitehall Road, Leeds, "Germanium and Silicon Power Rectifiers," T. H. Kinman, G. A. Carrick, R. G. Hibberd and A. J. Blundell, 6.30 p.m.——E. MIDLAND CENTRE: E.M.E.B. Service Centre, Derby, "Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33kV and Above," A. Morris Thomas and D. F. Oakeshott, 6.30 p.m.——CAMBRIDGE RADIO AND TELECOMMUNICATION GROUP: Cavendish Laboratory, Free School Lane, Cambridge, "The Use of Transistors in Radio and Television," A. J. Biggs and E. Wolfendale, 8 p.m.

Wed., Jan. 23.—LONDON GRADUATE AND STUDENT SECTION: Visit to Edison Swan Electric Company, Ponders End, Middlesex, "Mass Production of Lamps," 2 p.m.——RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, "Junction-Transistor Bootstrap Linear Sweep Circuits," K. P. P. Nambier and A. R. Boothroyd; "Design Considerations for Junction-Transistor Oscillators for the Conversion of Power from Direct to Alternating Current," F. Oakes; "Minority-Carrier Storage in Semi-Conductor Diodes," J. C. Henderson and J. R. Tillman, 5.30 p.m.——E. ANGLIAN SUB-CENTRE: Assembly House, Norwich, "A Transatlantic Telephone Cable," M. J. Kelly, Sir Gordon Radley, G. W. Gilman and R. J. Halsey, 7.30 p.m.

Thurs., Jan. 24.—ORDINARY MEETING: Savoy Place, London, W.C.2, Symposium of Papers on "The Transatlantic Telephone Cable," joint meeting linked by the cable with the American Institute of Electrical Engineers and the Engineering Institute of Canada, 6.45 p.m.

Fri., Jan. 25.—N.E. CENTRE: Carlisle Technical College, Carlisle, "Electrical Energy from the Wind," E. W. Golding, 7 p.m.

Sat., Jan. 26.—LONDON GRADUATE AND STUDENT SECTION: Visit to British Railways, Ilford Running Sheds, "Maintenance of Multiple-Unit Trains," 10 a.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., Jan. 22.—S.W. BRANCH: R.W.A. School of Architecture Library, Bristol, "Process Steam," L. G. Northcroft, 6.30 p.m.

Wed., Jan. 23.—LIVERPOOL AND DISTRICT BRANCH: The College of Buildings, Clarence Street, Liverpool, "School Heating Systems," C. A. Reynard, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Fri., Jan. 25.—LONDON MEETING: Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Snow," E. W. H. Vallis, 5.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Jan. 23.—Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Diesel Locomotive Building and Maintenance," T. F. B. Simpson, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Jan. 18.—GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, Thomas Lowe Gray Lecture, "The Salvaging of Ships with Particular Reference to the 'Empress of Canada,'" W. R. Colbeck, 6 p.m.

Sat., Jan. 19.—N.E. GRADUATE SECTION: Visit to National Coal Board Dean and Chapter Colliery, Ferryhill, 10 a.m.

Mon., Jan. 21.—SCOTTISH A.D. CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Aspects in the Development of the Medium-Weight Commercial Vehicle," E. B. Stead, 7.30 p.m.——MIDLAND GRADUATE SECTION: James Watt Memorial Institute, Birmingham, "Automation and its Social and Economic Implications," L. L. Goodman, 6.45 p.m.

Tues., Jan. 22.—SCOTTISH BRANCH: Royal College of Science and Technology, George Street, Glasgow, "Motive Power on Sea and Land," T. A. Crowe, 7.30 p.m.——WESTERN BRANCH: Engineering Laboratories, University Walk, Bristol, "The Impact of Engineering on Society," Sir Maurice Bowra, 7 p.m.——BIRMINGHAM A.D. CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Stop, Tail and Direction Indicator Lamps," J. H. Nelson, 6.30 p.m.——N.W. A.D. CENTRE: Liverpool Corporation, Passenger Transport Department Offices, Liverpool, "Jet Engines: Some Aspects of Their Design, Operation and Manufacture," A. W. Vickers, 7.15 p.m.——EASTERN GRADUATE SECTION: Town Hall, Luton, "Stress Analysis," R. Stanghan, 7 p.m.

Wed., Jan. 23.—SCOTTISH BRANCH: Technical College, Dundee, "Motive Power on Sea and Land," T. A. Crowe, 7 p.m.——SOUTHERN BRANCH: Royal Aircraft Establishment, Technical College, Farnborough, Hants, Annual General Meeting, 7.30 p.m.

Thurs., Jan. 24.—APPLIED MECHANICS GROUP: 1, Birdcage Walk, London, S.W.1, Discussion on "Diagnosis of Mechanical Troubles," 6.45 p.m.——N.W. BRANCH: Liverpool Engineering Society's Rooms, 9, The Temple, 24, Dale Street, Liverpool, Joint Meeting with the Merseyside Centre, "The Pressurised Water Reactor as a Source of Heat for Steam Power Plants," J. M. Kay and F. J. Hutchinson, 6 p.m.; Technical College, Preston, "A Standard Gas Turbine to Burn a Variety of Fuels," G. B. R. Feilden, J. D. Thorn and W. J. Kemper, 7 p.m.——E. MIDLANDS GRADUATES SECTION: College of Further Education, Greenclose Lane, Loughborough, "Operating Mechanisms for Circuit Breakers," J. C. Deeley, 7.15 p.m.——N.E. GRADUATE SECTION: Vane Arms, Stockton, "Production Planning and Budgeting in a Small Factory," W. Peacock and D. R. Gibbons, 7 p.m.

Fri., Jan. 25.—1, Birdcage Walk, London, S.W.1, General Meeting in Conjunction with the Automobile Division and the Internal Combustion Engine and Lubrication Groups, "An Investigation into the Mechanism of Oil Loss Past Pistons," P. de K. Dykes, 6 p.m.; "A Study of Piston Ring Lubrication," Samuel Eilon and O. A. Saunders, 6 p.m.

INSTITUTION OF NAVAL ARCHITECTS AND INSTITUTE OF MARINE ENGINEERS

Thurs., Jan. 24.—SOUTHERN JOINT BRANCH: Southampton Technical College, St. Mary Street, Southampton, "Air Conditioning of Ships," J. K. W. MacVicar, 7.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., Jan. 23.—INFORMAL MEETING: Waterloo Bridge House, London, S.E.1, "The Utilisation, Review and Planning of a Large Junction Network," J. B. F. Williams, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Jan. 18.—GLOUCESTER SECTION: Wheatstone Hall, Gloucester, "The Ings of Industry," W. H. Telling, 7.30 p.m.

Mon., Jan. 21.—NORTH EASTERN BRANCH: Neville Hall, Newcastle upon Tyne," "Production of Turbine Blading," R. Pickard, 7 p.m.

Tues., Jan. 22.—TEES-SIDE BRANCH: Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "Precision Casting," J. S. Turnbull, 7 p.m.

Wed., Jan. 23.—WORCESTER BRANCH: Cadena Café, Worcester, "Broaching and Broaching Techniques," A. E. Randall, 7.30 p.m.

Thurs., Jan. 24.—N. IRELAND BRANCH: Kensington Hotel, College Square East, Belfast, "The Blending of High-Quality with Low Cost in Engineering Production," J. Loxham, 7.30 p.m.——S. WESTERN REGION: Camborne School of Mines, Camborne, Film, "Production of Modern Lubricants and Some Industrial Applications," B. V. Harris, 7.15 p.m.——SOUTHERN REGION; Polygon Hotel, Southampton, "Punched Card Systems as an Aid to Production," A. E. Parish, 7.15 p.m.

Fri., Jan. 25.—S. WALES REGION: The Institute of Engineers, Park Place, Cardiff, "Human Relations in Industry," D. W. Collier, 7 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

To-day, Jan. 18.—LEICESTER SECTION: Bell Hotel, Leicester, "Modern Developments in the Use of Nylon in the Rubber Industry," J. M. Page, 7.30 p.m.

Mon., Jan. 21.—MERSEYSIDE SECTION: Liverpool Corporation Passenger Transport Office, 24, Hatton Garden, Liverpool, "Recent Technical Developments," W. P. Fletcher, 7.15 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Jan. 22.—LANCASHIRE AND CHESHIRE BRANCH: College of Technology, Manchester, "Instability Effects in the Plastic Range," W. Merchant, 6.30 p.m.——SCOTTISH BRANCH: Institution of Engineers and Shipbuilders, Glasgow, "Unusual Industrial Structures," H. C. Husband, 7 p.m.

Thurs., Jan. 24.—11, Upper Belgrave Street, London, S.W.1, "Water Towers," J. O. C. Ritchie, 6 p.m.

Fri., Jan. 25.—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Birmingham, "The Calculation of Bending and Torsional Effects in Girders," J. S. Terrington, 6 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Jan. 18.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The History of Diving," C. E. T. Warren, 7 p.m.

Fri., Jan. 25.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Mechanical Aim and Progress in Fire Fighting Equipment," Edmund S. Calvert, 7 p.m.

LIVERPOOL ENGINEERING SOCIETY

Wed., Jan. 23.—Society's Rooms, 24, Dale Street, Liverpool, "Electronic Control of Machine Tools," N. Milne, 6 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Jan. 25.—Engineers' Club, Albert Square, Manchester, Joint Meeting with the Institute of Petroleum, "Smokeless Zones," General Open Discussion, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Wed., Jan. 23.—STUDENT SECTION: Bolbec Hall, Newcastle upon Tyne, "Towing Tank Procedure," J. R. Fulcher, 6.45 p.m.

Fri., Jan. 25.—Lecture Theatre, Mining Institute, Neville Hall, Newcastle upon Tyne, "A Method of Analysing Voyage Data," R. E. Clements, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., Jan. 24.—MAIN LECTURE: Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Aeronautical Research in Holland," H. J. van der Maas, 6 p.m.

ROYAL SOCIETY OF HEALTH

Thurs., Jan. 24.—SWANSEA SESSIONAL MEETING: Guildhall, Swansea, "The Usk Dam and Water Undertaking," T. Price, 10 a.m.

SOCIETY OF CHEMICAL INDUSTRY

Thurs., Jan. 24.—CORROSION GROUP: Battersea Polytechnic, Battersea Park Road, London, S.W.11, Conversazione, 6.30 p.m.